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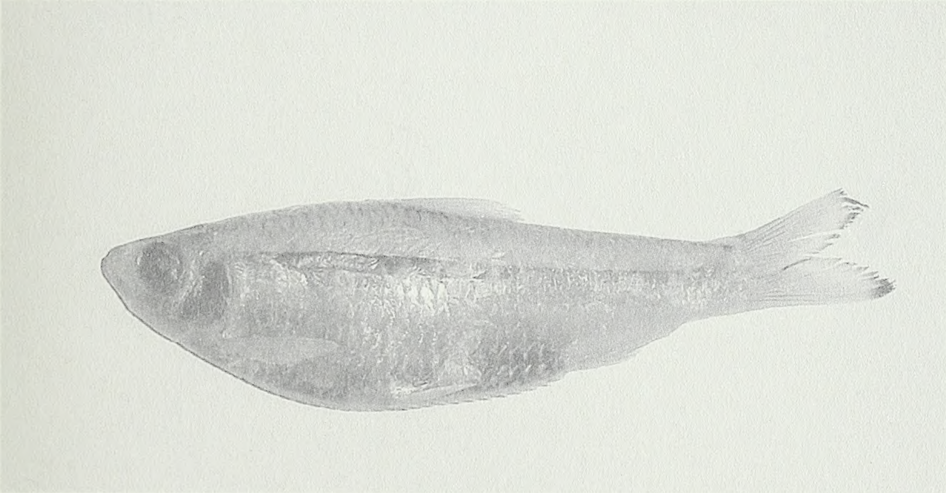

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SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

CALL FOR PAPERS

2002 ANNUAL MEETING

June 7–8, 2002

CLAREMONT MCKENNA COLLEGE

CLAREMONT

Contributed Papers & Posters: Both professionals and students are welcome to submit abstracts for a paper or poster in any area of science. Abstracts are required for all papers, as well as posters, and must be submitted in the format described below. Maximum poster size is 32 by 40 inches.

Symposia: The following symposia are planned at the present time. If you wish to participate or to organize any additional symposia, please contact the organizer or the Academy Vice President, Ralph Appy (310 732 3497) rappy@portla.org. Organizers should have a list of participants and a plan for reaching the targeted audience.

Friday, June 7, 2002

Virtual Oceans
Judy Doino Lemus jdlemus@usc.edu 213-740-1965

Marine Monitoring in the Southern California Bight
Stephen Weisberg 714-372-9203 stevew@sccwrp.org

Aerial Particulate Contaminants
Ralph Appy rappy@portla.org 310-732-3497

Poster Session: 5 pm
Scientific Illustrators exhibit at Poster Session

Plenary Speaker: Gregor Hodgson, "John Q. Public Saves Coral Reefs"

Saturday, June 8, 2002

Rocky Reef Monitoring
Dan Pondella pondella@oxy.edu (323) 259-2955 and Bob Grove grovers@sce.com 626-302-9735

Conservation Management
Brad Blood BBlood@sapphosenvironmental.com 626-683-3547

Effects of Exotic Species on Southern California Wildlife
Dan Guthrie dguthrie@jsd.clarement.edu 909-607-2836 and Andrew Jirik ajirik@portla.org

High School Research Participation Program Presentations:
Gloria Takahashi 626-333-2173, myopick@aol.com

Short Course on Sea Urchin Toxicity Test Methods for Conducting Marine Environmental Research
Stephen Bay (SCCWRP) and Michelle Anghera (UCLA)

Plenary Speaker: Walter Fitch, U.C. Irvine, "Creation Science: An Oxymoron?"

There will be additional sessions of Invited Papers and Posters and of papers by Junior Academy members.

Student Awards: Students who elect to participate are eligible for best paper or poster awards in the following categories. Biology: ecology and evolution, biology: genetics and physiology, physical science. A paper by any combination of student and professional co-authors will be considered eligible provided that it represents work done principally by student(s). In the case of an award to a co-authored paper, the monetary award and a one year student membership to the Academy will be made to the first author only.

For further information on posters, abstracts, registration and deadlines, see the Southern California Academy of Science web page at: jsd.claremont.edu/scas/

Short Course Description for Presentation at SCAS 2002 Annual Meeting
Saturday, June 8, 2002; 8 a.m.–noon

Sea Urchin Toxicity Test Methods for Conducting Marine Environmental Research

Instructors:
Steven Bay (SCCWRP)
Michelle Anghera (UCLA)
Co-sponsored by the Southern California Regional Chapter of SETAC

This is a "hands-on" short course intended to provide graduate students and faculty with the skills and background needed to conduct environmental research with the gametes and embryos of sea urchins and sand dollars. The course will use the locally abundant purple sea urchin (*Strongylocentrotus purpuratus*) as the test organism. Laboratory toxicity tests provide the foundation for many types of environmental toxicology research. Toxicity tests also provide an excellent laboratory tool for independent student research and provide a mechanism to integrate many different disciplines (biology, chemistry, mathematics) into interesting classroom activities. Early life stage tests using sea urchins are particularly attractive for this research because the animals are easily obtained and held in the laboratory and several sensitive test methods have been developed using sperm and embryos. These tests are widely used in monitoring and research programs throughout the world and can be conducted on a modest budget and in a short period of time.

This course will introduce the participants to the applications of sea urchin toxicity tests in environmental research and discuss opportunities for careers and academic research in this field. The participants will conduct a complete toxicity test during the class and observe additional techniques needed to conduct other test methods. The applications of sea urchin toxicity tests in environmental research will be illustrated with examples from the instructors' recent investigations into the environmental effects of contaminated sediment and stormwater runoff.

This class is free to SCAS meeting registrants, but size is limited to 20 participants. Participants should be familiar with basic laboratory techniques, including the preparation of dilutions from stock solutions, operation of pipettes, and use of a compound microscope. All class materials will be provided by the instructors.

CALL FOR MENTORS

The **Research Training Program** of the Southern California Academy of Sciences is receiving a large number of applications from students for the 2002–2003 academic year. This is in large part due to an excellent article in the **Los Angeles Times** about the program and success of students enrolled in it. The program involves the placement of high school students with excellent scientific backgrounds from throughout southern California in scientific laboratories to conduct research under research mentors. The projects are usually designed by the mentor. Students spend about 8 hours a week on their projects, commencing in September and concluding in May with the presentation of their results at the Annual Meeting of the Academy.

We are seeking scientists who might like to become mentors for these outstanding students in the coming year. If you or your graduate students have room in your lab for a student, please let us know. We need your name, address, contact numbers (include e-mail) and an indication of research area. Forward the above information to:

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101(1), 2002, pp. 1–12

A New Species of the Genus *Lile* (Clupeiformes: Clupeidae) of the Eastern Tropical Pacific

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[2]*Universidad Autónoma de Baja California. Facultad de Ciencias, Apdo. Postal 1653, Ensenada, Baja California 22800 México.*
[3]*Centro de Investigaciones Biológicas del Noroeste, S.C. Laboratorio de Ictiología, Apdo. Postal 128, La Paz, Baja California Sur 23001 México.*

Abstract.—A new species of tropical sardine belonging to the genus *Lile* is described. The species differs from other known members of the genus by its morphometrics, morphology, number of gill rakers, coloration and distributional pattern. This new taxon represents the third known species of the genus *Lile* for the eastern tropical Pacífic.

Resumen.—Se describe una especie nueva de sardina tropical que pertenece al género *Lile.* Difiere de los otros miembros de este género por su morfometría, morfología, número de branquiespinas, coloración y patrón de distribución geográfica. Ésta es la tercera especie, de este género, que se conoce en los litorales del Pacífico oriental tropical.

The Clupeidae, order Clupeiformes, is divided into five subfamilies. One of them, Clupeinae, contains 15 genera and almost 80 species widely distributed through temperate, subtropical and tropical seas of the world's oceans (Whitehead 1985). The genus *Lile* Jordan and Evermann 1896 of subfamily Clupeinae, is exclusive to tropical and subtropical waters of Middle and South America. Besides the new species described here, three other *Lile* species are known: (1) *L. stolifera* (Jordan and Gilbert 1882), with a disjunct distribution from Bahía Magdalena, Baja California Sur (BCS) and Golfo de California to northern Nayarit, México, and from Costa Rica to Perú; (2) *L. piquitinga* (Schreiner and Miranda-Ribeiro 1903) which inhabits the fresh and brackish waters of the Atlantic drainage of Venezuela and Brazil; and (3) *L. gracilis* Castro-Aguirre and Vivero 1990, known from Jalisco, México to Golfo de Fonseca, Honduras.

Methods

All body measurements and counts of fin rays, gill rakers, ventral scutes, and midlateral scales were taken based on Whitehead's methods (1985). Original morphometric data were transformed to thousandths of the cephalic length or standard length and descriptive statistics (mean, standard deviation, mode, and range) were computed. An analysis of discriminant function (Statistica 4.2 program) was used to identify the most important biometric characters to classify *Lile nigrofasciata* and *L. stolifera.*

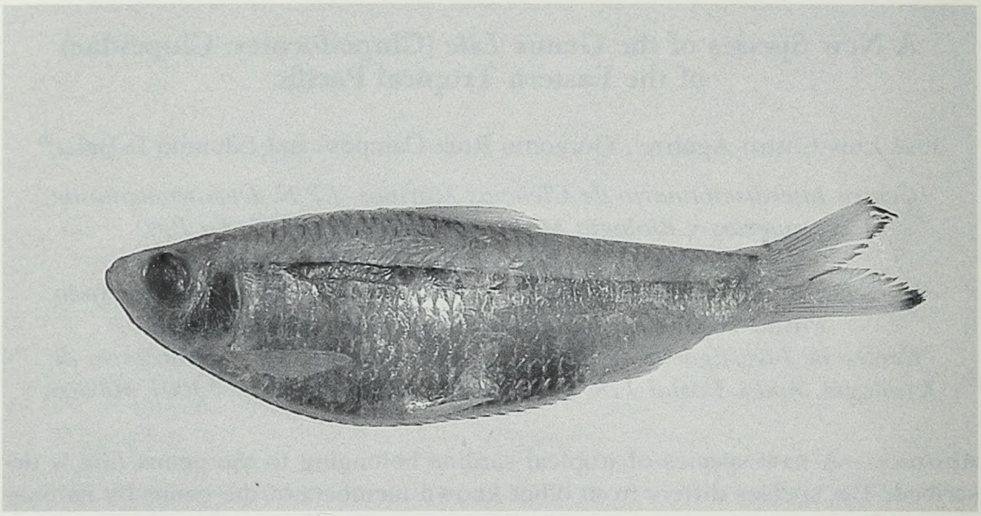

Fig. 1. Holotype of *Lile nigrofasciata* (CI: 2032), adult female, 104 mm SL, Bahía de Guásimas, Sonora, México. Photograph by Gorgonio Ruiz-Campos.

Abbreviations of the fish collections where the studied specimens are deposited are as follows: CI, Centro Interdisciplinario de Ciencias Marinas (CICIMAR, I.P.N.), La Paz, BCS; UABC, Facultad de Ciencias, Universidad Autónoma de Baja California, Ensenada, Baja California; ENCB-I.P.N., Departamento de Zoología, Escuela Nacional de Ciencias Biológicas, México, D.F.; CIB, Centro de Investigaciones Biológicas del Noroeste, S.C., La Paz, BCS; IBUNAM, National Fish Collection at the Instituto de Biología, Universidad Nacional Autónoma de México, México, D.F.; CAS, California Academy of Sciences, San Francisco, California, U.S.A.; and LACM, Natural History Museum of Los Angeles County, Los Angeles, California (cf. Other material examined in Appendix 1). Number of specimens examined is indicated in parenthesis.

Results

Lile nigrofasciata sp. nov. (Fig. 1).

Holotype.—CI: 2032, a female of 104 mm standard length (SL) from Bahía de Guásimas, Sonora, México, collected by E.F. Balart and A. Arreola Lizárraga, 23 Feb. 1996, at a depth of 1.5 m.

Paratypes.—CI: 2039 (1), 98 mm SL collected along with the holotype; IBUNAM: P9520 (2), 96.0–100.0 mm SL, *idem*; CIB: 3001 (2), 93.1–94.5 mm SL, *idem.* CI: 1886 (50), 56.5–77 mm SL, Santispac, Bahía Concepción, BCS, collected by P.J.P. Whitehead, 29 Nov. 1988. CI: 4922 (35), 74.1–86.0 mm SL, Estero El Conchalito, Ensenada de La Paz, BCS, México, collected by A.F. González-Acosta, 18 Aug. 1997.

The results of the morphometric and meristic analysis are listed in the Table 1.

Diagnosis.—A species belonging to the genus *Lile,* with the following differential characteristics: body elongate, very compressed and high, its maximum depth 3.3 to 4.4 (mean = 3.7) times in standard length; dorsal and ventral profiles convex; 36 to 40 (mode = 38) gill rakers on lower limb of the first gill arch; 34

to 49 (mode = 40) midlateral scales; 14–18 (mode = 16) prepelvic scutes; 10–16 (mode = 12) postpelvic scutes; dorsal and anal fins with 13–17 (mode = 15) and 14–16 (mode = 16) rays, respectively; head relatively small, its maximum length 3.7 to 5.4 (mean = 4.2) times in standard length; body with a dark green (in life) or black (in alcohol) band extended from the supraposterior edge of the opercle to the final part of the caudal peduncle; iris black; pupil translucent, whitish or lightly gray; most of individuals examined have both tips of their caudal lobes with a black stain; color of the opercle in specimens <70 mm SL is gray-silver, and in those >80 mm SL with a dark gray or black stain.

Description.—Body elongate, fusiform, compressed, with dorsal profile arched and the ventral profile notably convex. Cephalic region spindle-shaped; mouth oblique, almost vertical. Head relatively small, its length 3.7 to 5.4 (mean = 4.2) times in standard length; eye large, its diameter 2.4 to 4.1 (mean = 3.0) times in cephalic length; preorbital distance shorter than eye diameter and contained 3.1 to 5.2 (mean = 3.9) times in cephalic length; postorbital distance longer than eye diameter and contained 1.9 to 3.2 (mean = 2.6) times in cephalic length. Posterior edge of opercle rounded and flat, not serrated, but with a concave notch on its post-distal part. Preopercle flat, its posterior edge straight, shallowly oblique and directed anteriorly where it connects with the rounded suborbital. A distinctive membranous structure on anterior edge of cleithrum that appears juxtaposed to first lateral scales, and covered with a great number of highly ramified complex tubules. Tubular system extended to nuchal region where it connects to other side of body by means of a tubular system. Two anterior fontanels located between supraocular and nuchal regions, distinguishable as two dark areas, also identified as a complex tubular system connected with those of the preopercle, opercle, and membranous structure. Mouth terminal, protrusible, forming a tubular structure composed of two supramaxillary bones, which are associated with the maxillary bone. Both sides of symphysis of lower jaw with several series of conical, blunt, minute teeth. Inner border of jaws without teeth; conical and unicuspidated teeth forming a conglomerate on the palatines. Tongue spatulate and lacking teeth. Six branchiostegal rays supported by flexible ligaments. Lower limb of the first gill arch with 36 to 40 (mode = 38) thin elongate gill rakers, closely approximated. The pseudobranch has from 13 to 14 relatively thick filaments. Body elongate, compressed, deep, maximum depth 3.3 to 4.4 (mean = 3.7) times in standard length; dorsal profile arched, ventral profile notably convex. The ventral scutes originate from the first scale behind the isthmus and finish before the anal pore; their numbers range from 14 to 18 (mode = 16) prepelvic and 10 to 16 (mode = 12) postpelvic or preanal. Origin of dorsal fin situated before that of the pelvic fins and closer to tip of mouth than to base of caudal peduncle. Dorsal fin length is almost equal to the cephalic length; dorsal rays from 13 to 17 (mode = 15), the last two rays highly ramified. Pectoral fins relatively small, falciform, their length almost equal as the cephalic length; insertion of pelvic fins begins at post-distal part of gill opening and above the thoracic border. Pelvic fins small, their maximum length 1.6 to 2.5 (mean = 1.9) times in cephalic length, and 8 branched rays. Anal fin short, not very high, with a scaly sheat, and 14 to 16 rays (mode = 16), the last two rays branched; anal fin situated at posterior one-third of the body. Caudal fin forked, 5–11 upper procurrent rays, 10 upper principal rays (9 of them forked), 9 lower principal rays (8 of them forked), and 6–9 lower pro-

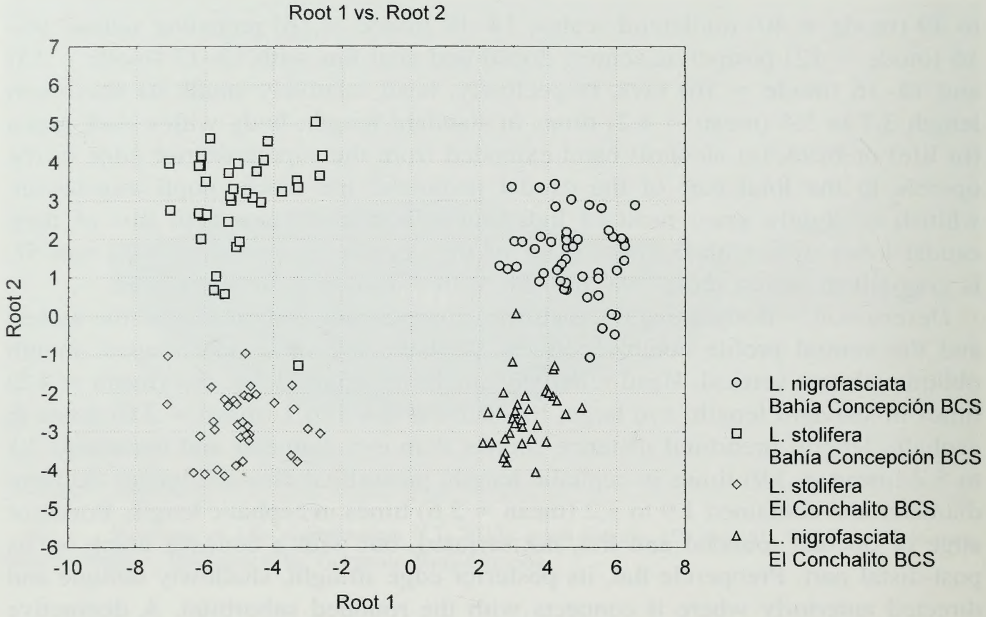

Fig. 2. Discriminant function analysis of populations of *Lile* spp. in the Gulf of California, México. Axis 1 vs. Axis 2. Pooled data.

current rays. Scales large, somewhat deciduous, with smooth border, four continuous grooves and one discontinuous of central position, the nearest groove to the lower border has the form of an arch, the other cross the entire scale. Number of scales in lateral series varies from 34 to 49 (mode = 40); predorsal scales 11–13. Total vertebrate 40–41 (mode = 41), 14 or 15 (mode = 15) caudal. Predorsal bones (=upperneurals) between cranium and the first dorsal finrays 9–11 (mode = 11). Caudal complex with two (60%) or three (40%) epurals.

Biometric Analysis.—Twenty-one biometric variables of 85 examined specimens of *Lile nigrofasciata* and 71 *L. stolifera* were analyzed. Wilks' Lambda values varied from 0.0027 to 0.0204, suggesting a strong discrimination between the species (Wilk's Lambda for all variables combined: 0.00273, approx. $F_{(63, 394)} = 39.010$, $p < 0.0000$). The values of tolerance ranged between 0.4974 and 0.9002. The classification matrix obtained here indicates that 100% of the examined individuals were correctly classified for the populations of *Lile nigrofasciata* (Bahía Concepción and El Conchalito, BCS), as well as that of *L. stolifera* from El Conchalito, BCS. The specimens of *L. stolifera* from Bahía Concepción were correctly classified with an accuracy of 97.22%.

Only three of the 21 biometric variables analyzed contributed significantly to the discrimination of both species of *Lile:* interorbital distance ($p < 0.00001$), number of midlateral scales ($p < 0.00003$), and number of gill rakers on the lower limb of the first gill arch ($p < 0.00000$).

The squared Mahalanobis distances were significantly greater between populations of *L. nigrofasciata* and *L. stolifera,* but were not significant between populations of the same species, as shown in the graph of the discriminant function analysis (Fig. 2).

Coloration.—Living specimens, with the exception of the olive-green or black midlateral band, are yellowish-green and somewhat translucent in their predorsal region. The head is also yellowish-green, with a gray-silver spot on the preopercle and opercle as result of a great concentration of black pigment inside the branchial chamber. Gums and distal part of the lower jaw are black. The upper lip and internasal area are black or dark gray. The gill filaments are whitish or yellowish. The oral chamber is whitish. A distinctive black or dark line travels from the nape to the dorsal fin origin and to the precaudal area. The iris is black or dark gray, the pupil is whitish and translucent. In most individuals both caudal lobes are tipped black, although some of them have only the upper lobe with a faint black tip. Anal, pectoral, and pelvic fins are yellowish or whitish.

Habitat.—The holotype and five paratypes were caught in 1.5 m in Bahía de Guásimas, Sonora, near the town of the same name. This coastal lagoon, with anti-estuarine circulation and muddy-sandy bottom, is located at the geographical coordinates, 27°54′ and 27°59′ N, and 110°48′ and 110°55′ W. Water conditions at capture were: salinity, 45 ppt (annual range for 1996, 35–45 ppt), temperature, 20.5°C (annual range for 1996, 14–30°C), and Secchi disc visibility, 0.72 m. The dominant fish species at the type locality were *Ariopsis seemani, Anchovia macrolepidota, Mugil cephalus, Diapterus peruvianus, Anchoa* spp., *Eucinostomus* spp., and *Colpichthys regis.* The other paratypes from Bahía Concepción and Ensenada de La Paz (Manglar El Conchalito), BCS, were collected in shallow littoral areas with soft silt, and were usually associated with mangrove roots that border these coastal lagoons. The fish communities at both BCS sites were represented by the following dominant species: *Eucinostomus* spp., *Diapterus peruvianus, Anchovia macrolepidota, Mugil cephalus* and *Lile stolifera.* In addition, voucher specimens captured at oligohaline conditions (5.0–15 ppt) in the coastal lagoon of Tres Palos, Guerrero, México, were also examined. Other specimens of the new species were collected in the Oriental, Occidental, Inferior and Superior coastal lagoons, Oaxaca, as well as in the Mar Muerto, Chiapas, in salinities of ≥35.5 ‰. In these last five localities the fish composition is very similar, but *Lile gracilis* replaces to *L. stolifera.*

Etymology: The name *nigrofasciata* alludes to the obvious dark or black band that travels the midlateral part of the body, from the posterior edge of the operculum to the end of the caudal peduncle.

Key to the species of Lile of the eastern tropical Pacific

1. Midlateral band dark or black green; iris black; pupil translucent, dark gray or black; 36–40 (mode = 38) gill rakers on lower limb of the first gill arch .... *Lile nigrofasciata* (Fig. 3A).
   Midlateral band silvery; iris yellow or golden-silvery; pupil black, not translucent; 24–32 gill rakers on lower limb of the first gill arch 2
2. Origin of dorsal fin located ahead of or on a vertical through the insertion of the pelvic fins; 27–42 midlateral scales in a longitudinal series; ventral profile notably convex; body depth 2.8–3.7 times in standard length; tips of both caudal lobes with conspicuous black blotches ... *Lile stolifera* (Fig. 3B).
   Origin of the dorsal fin located behind the insertion of the pelvic fins; 34–36 midlateral scales in a longitudinal series; ventral profile slightly convex

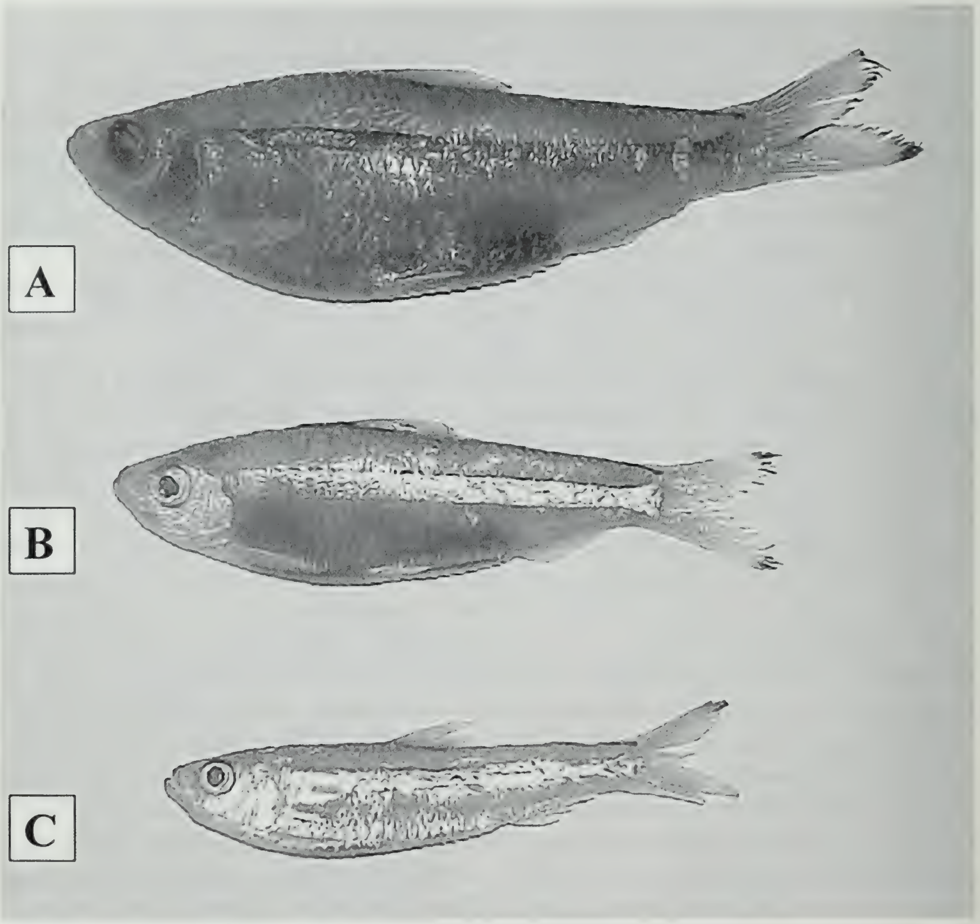

Fig. 3. Comparison of the three species of the genus *Lile* of the Eastern Tropical Pacific. (A) *Lile nigrofasciata* sp. nov. (holotype, CI: 2032, 104 mm SL), Bahía de Guásimas, Sonora. (B) *Lile stolifera* (CI: 4738, 83 mm SL), Manglar El Conchalito, Baja California Sur. (C) *Lile gracilis* (ENCB-IPN: 7134, 71.4 mm SL), Mouth of Río Balsas, Guerrero. Photograph by Gorgonio Ruiz-Campos.

or straight; body depth 4.0–5.5 times in standard length; only the upper tip, if any, of the caudal fin with a faint dark mark .... *Lile gracilis* (Fig. 3C).

Geographical distribution.—Based on material examined deposited in the ichthyological collections previously mentioned, *Lile nigrofasciata* is distributed in the Bahía Magdalena-Bahía Almejas lagoon complex in the southwestern Baja California Sur, México, the Golfo de California (Bahía de Guásimas, Sonora; Bahía Concepción and Manglar El Conchalito at Ensenada de La Paz, BCS), and along the western coast of Mexico and Central America, to Colombia, Ecuador and northern Perú.

Discussion

The recognition of this new species is interesting from a systematic and biogeographic point of view. Its closest relationship is with *Lile stolifera,* based on the position of the dorsal fin in relation to that of the pelvic fins, both species having the origin of the dorsal fin ahead of the insertion of the pelvics. This characteristic is also observed in the Atlantic species *L. piquitinga* (distributed from Venezuela to Brazil) but not in *L. gracilis* (distributed from the central Pacific of México to Honduras) whose individuals have the dorsal fin origin slightly behind the origin of pelvic fins (Castro-Aguirre and Vivero 1990). *L. stolifera* and *L. nigrofasciata* are distinguished by gill-raker numbers on the lower limb of the first gill arch, the first species with 24 to 31 (mode = 27), the second with 36 to 40 (mode = 38).

The size and form of the scales also different; *L. stolifera* has small scales (average maximum length 3 mm) in the form of a shield with their posterior edges smoothly convex; in contrast, the scales of *L. nigrofasciata* measure on average 5 mm in maximum length, and their posterior edges are angular with the sharp tips. The most conspicuous diagnostic characteristic is coloration; *L. stolifera* has a brilliant silvery midlateral band, golden-yellow or silvery-golden iris, black (no translucent) pupil. In comparison, *L. nigrofasciata* has a dark or black-green midlateral band, dark or black gray iris, and the translucent gray pupil. Both species share characters such as the numbers of scales in a longitudinal series, ventral scutes, and anal rays (Table 1), and filaments of the pseudobranch (12 to 14). Based on five cleared-and-stained specimens of both species, a preliminary osteological study revealed some interesting facts: whereas the total vertebrae number are almost the same in *L. stolifera* and *L. nigrofasciata* (41–42 vs. 40–41), the caudal vertebrae number is not. *L. stolifera* has 16 to 17 (16) caudal vertebrae and *L. nigrofasciata* has 14 to 15 (15). On the other hand, *L. gracilis* has 38 to 40 (38) total vertebrae number and 17 to 18 (17) caudal vertebrae number. In comparison, the Atlantic species *L. piquitinga,* has 38 to 41 total vertebrae and 14 to 15 caudal vertebrae (Gómez-Gaspar 1976). *L. stolifera* has 8 to 10 (9) predorsal bones, *L. nigrofasciata* 9 to 11 (11), and *L. gracilis* 8 to 9 (9), very near to *L. stolifera,* but the first bone of the series is larger than in the other species (Fig. 4). *L. piquitinga* has 7 to 8 predorsal bones (Gómez-Gaspar 1976; McGowan and Berry 1984). Two or three epural bones were observed in the caudal skeleton of *L. nigrofasciata* (Fig. 5), whereas in *L. stolifera* two epural bones is the most frequent situation (80%) and rarely three. Vivero and Romero-Castillo (1990) found two epural bones in *L. gracilis;* however, in very small specimens (e.g. 35.6 mm) three epural bones can be observed; in some the double character of the second epural bone is still evident. Some osteological studies have shown that in some species of Clupeiformes the fusion of one pair of epural bones is relatively common during larval development (Balart 1985; Matsuoka 1998).

The geographical ranges of both species also differ (Fig. 6): *Lile nigrofasciata* has a widespread distribution in the eastern tropical Pacific, while *L. stolifera* has a quasi-antitropical distribution. Both species are sympatric from Bahía Magdalena-Bahía Almejas coastal lagoon complex in the northwestern Baja California Sur and both coasts of Golfo de California to Bahía Banderas, Jalisco, México. The distribution of *Lile stolifera* is interrupted from northern Bahía Banderas, appearing again as sympatric with *L. nigrofasciata* from Costa Rica to Perú (Castro-Aguirre et al. 1999). *L. nigrofasciata* is also sympatric with *L. gracilis* from

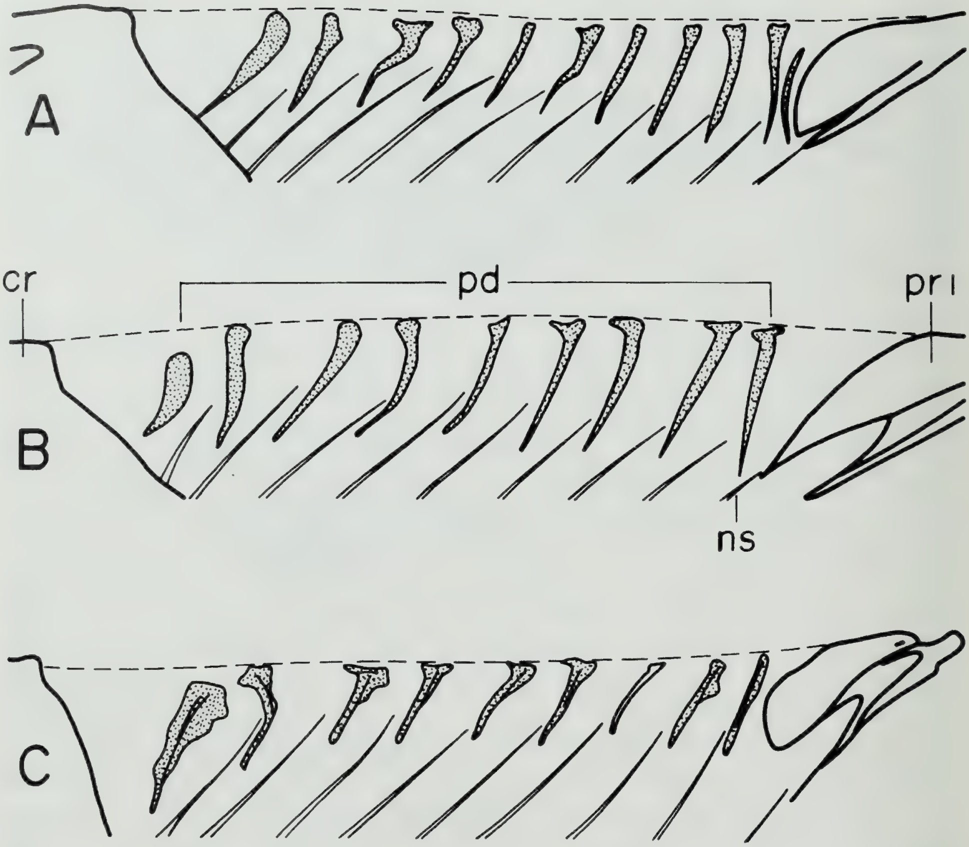

Fig. 4. Characteristic arrangement of predorsal bones (left lateral view) in Pacific species of *Lile*. (A) *L. nigrofasciata* sp. nov., (B) *L. stolifera* and (C) *L. gracilis*. cr, cranium; ns, neural spine; pd, predorsal bone; pr, proximal radial of dorsal fin support.

the Mexican central Pacific to Golfo de Fonseca, Honduras (S. Contreras-Balderas, unpublished data).

Photographs of specimens identified as "*Lile stolifera*" that were provided by Chirichigno (1963: 14, fig. 5) and Yáñez-Arancibia ("1978" [1980]: 266, plate 12, fig. 4) correspond to *L. nigrofasciata.*

It is not feasible to present a probable phylogeny of the genus because more detailed anatomical studies of the four nominal species are needed, particularly the osteology of the caudal complex and the neurocranium, as well as a comparative study of their early ontogenic stages. Based on some osteologic aspects of *Lile gracilis,* Vivero and Romero-Castillo (1990) proposed that the allopatrical processes led to the persistence of neotenic characters. It is necessary, however,

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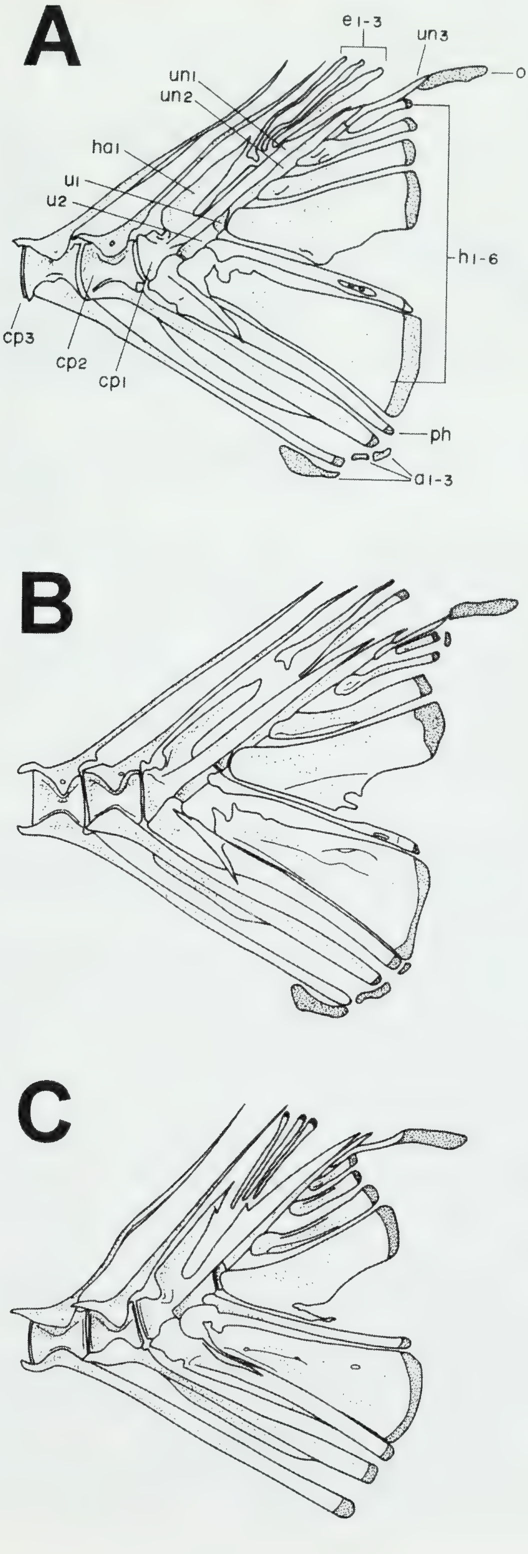
Fig. 5. Comparison of the caudal skeleton (left lateral view) of the three species of the genus *Lile* in the eastern tropical Pacific. (A) *L. nigrofasciata* sp. nov., (B) *L. stolifera* and (C) *L. gracilis*. a, radial cartilage; cp, preural centrum; e, epural; h, hypural; na, neural modified spine; o, opisthural cartilage; ph, parhypural; u, ural centrum; un, uroneural. Stippled areas, cartilage.


A
e1-3
un3
o
un1
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ha1
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h1-6
cp3
cp2
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a1-3
B
C

Table 1. Morphometry of *Lile nigrofasciata* sp. nov. and *L. stolifera.* Measurements according to Whitehead (1985).

	Lile nigrofasciata sp. nov. N = 85					*Lile stolifera* N = 71				
	Mean	Mode	Min	Max	s	Mean	Mode	Min	Max	s
Meristic measures										
Scales in lateral series	40	40	34	49	2.7	36	40	27	42	4.0
Gill rakers on lower limb of the first gill arch	38	38	36	40	1.1	27	27	24	31	1.5
Prepelvic scutes	16	16	14	18	0.8	16	16	13	18	0.9
Postpelvic or preanal scutes	12	12	10	16	1.1	12	13	10	14	1.0
Dorsal fin rays	15	15	13	17	0.8	15	15	14	18	0.8
Anal fin rays	15	16	14	16	0.7	15	15	13	19	1.0
Morphometric measures in thousandths of the standard length										
Cephalic length	239.3	225.4	185.7	271.2	14.4	237.7	250.0	208.3	269.2	10.6
Body depth	273.7	271.4	228.6	307.6	16.9	298.1	300.0	270.3	356.6	12.6
Predorsal length	442.5	438.6	338.7	491.6	20.7	440.2	423.7	400.0	475.0	18.9
Preanal length	754.1	746.5	677.4	885.7	34.6	749.4	721.3	694.9	902.8	30.7
Caudal peduncle length	122.9	121.2	101.6	157	11.5	128.4	125.0	101.7	151.4	10.4
Caudal peduncle depth	114.4	113.6	97.4	128.8	7.1	123.1	125.0	106.7	137.4	6.7
Pelvic fin length	127.4	136.4	103.7	145.2	9.2	130.5	125.0	117.6	146.2	7.3
Pectoral fin length	183.3	183.1	134.3	213.1	13.4	179.6	169.5	157.8	202.7	10.2
Preorbital length	62.2	70.4	46.3	78.7	6.7	63.8	67.8	51.3	75.5	6.2
Postorbital length	94.0	100.0	64.0	136.0	10.3	95.5	100.0	77.4	109.1	7.0
Eye diameter	81.0	85.7	59.2	99.4	7.3	84.9	84.8	70.6	105.3	6.3
Pupil diameter	43.3	45.5	35.1	57.1	5.0	47.4	50.9	36.5	60.0	6.4
Interorbital distance	62.3	57.1	40.3	85.4	10.7	73.6	67.8	61.0	90.9	5.4
Upper jaw length	105.6	100.0	61.4	121.4	9.3	105.9	101.7	87.7	121.1	6.1

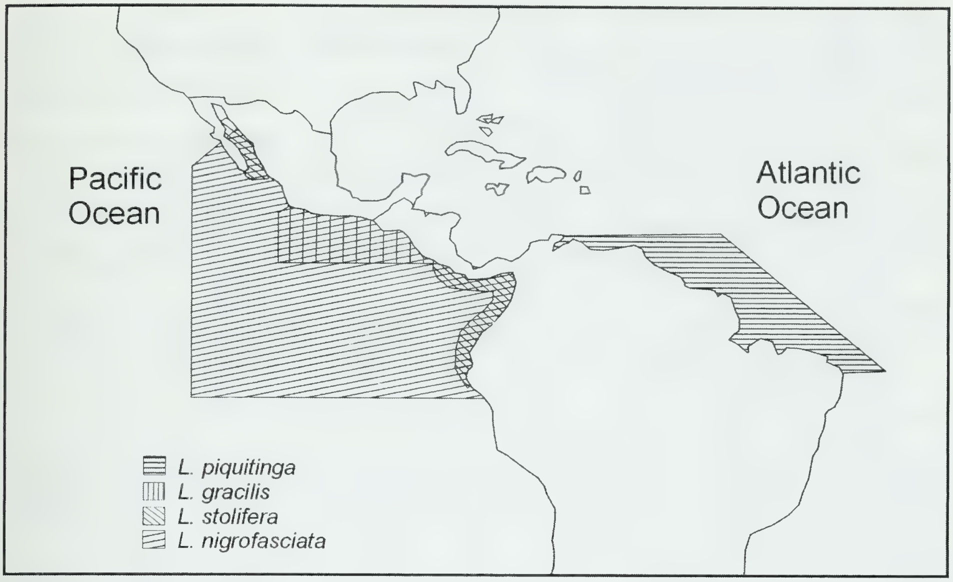

Fig. 6. Distribution ranges of the species of the genus *Lile* in tropical America.

to carry out finer studies to understand the evolutionary processes that gave origin to *L. gracilis,* the species that replaces *L. stolifera* in the central part of the tropical eastern Pacific.

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Appendix 1. Other Material Examined:

Lile nigrofasciata sp. nov. Baja California Sur, México: Ensenada de La Paz at Manglar [Estero de] El Conchalito, CI: 4954, 30(57.5–85.0 mm), 16-17/IX/1997, A.F. González Acosta; Bahía Magdalena at Estero San Buto [24° 46′ N, 112° 05′ W], CI: 4560, 1(110.0 mm), 4/VI/1984, coll.?; Bahía Magdalena at Estero Las Botellas [24° 26′ N, 111° 07′ W], CI: 778, 1(77.0 mm), 10/XI/1985, U. McGregor; Bahía Magdalena at Estero San Carlos [24° 47′ N, 112° 05′ W], CI: 2279, 2(77.0–78.0 mm), 8/XI/1990, R. Rodríguez; Bahía Magdalena at Puerto Chale [24° 43′ N, 111° 32′ W], CI: 1861, 1(98.3 mm), 14/IV/1986, F. García; Bahía Magdalena at Estero Médano Amarillo [24° 43′ N, 112° 02′ W], CI: 1894, 4(87.0–96.0 mm), 11/II/1981, J.L. Castro Ortíz. Guerrero, México: Laguna de Tres Palos [15° 48′ N, 98° 46′ W], CI: 2282, 63(33.0–61.0 mm), 24/IV/1991, P.J.P. Whitehead et al. Tumaco, Colombia, CAS: 213293, 20 (49.0–82.5 mm), 1913, A. Henn & C. Wilson.

Lile stolifera. Baja California Sur, México: Ensenada de La Paz at Manglar El Conchalito, CI: 4738, 7(79.0–86.0 mm), 22-23/IV/1997, A.F. González Acosta; Estero de San José del Cabo [22° 55′ N, 109° 46′ W], CI: 3279, 58 (56.0–71.0 mm), 17/V/1989, P.J.P. Whitehead & R. Rodríguez; Bahía San Juanico at Punta Pequeña, LACM: 32084, 73 (45–64 mm), 28/X/1971, C. Swift; Bahía Concepción at Isla Anegada, CI: 1011, 36(53.0–74.0 mm SL), 12/VIII/1990, J. Rodríguez et al.; Río Santa Rosalía [=San Luciano], LACM: 50296, 4 (47–62 mm), 12/III/1957, G.W. Barlow; Río Mulegé at 2.1–3.0 km above the mouth, UABC: 0180, 2(47.7–61.7 mm), UABC: 0191, 3(46.2–50.7 mm), UABC: 0204, 1(47.7 mm), 14/X/1995, G. Ruiz-Campos. Nayarit, México: Estero San Blas, LACM: 50485, 1(86 mm), 30/I/1958, B.W. Walker et al. Puerto Parker, Costa Rica, CAS: 146862, 10(54.0–73.5 mm), 12-22/I/1938, W. Beebe et al.

Lile gracilis. Guerrero, México: Mouth of the Río Balsas (La Barra de San Francisquito), ENCB-IPN: 7134, 6(53.0–74.0 mm), 24/II/1988, A. Marmolejo; and Río Balsas at Brazo de San Francisquito, CIB: 2501, 5(35.6–67.6 mm), 6/X/1993, F. de Lachica-Bonilla et al.

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Food habits of the spotted sand bass *Paralabrax maculatofasciatus* (Steindachner, 1868) from Laguna Ojo de Liebre, B.C.S., Mexico

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Abstract.—Feeding habits of spotted sand bass *Paralabrax maculatofasciatus,* in Laguna Ojo de Liebre, B.C.S., Mexico, were analyzed. According to relative importance index the amphipod *Corophium* spp., isopod *Paracerceis* spp., polychaetes *Pherusa* spp., crabs *Callinectes bellicosus* and fish were the most important items. Seasonal variations were observed during May-September, *Corophium* spp. and *Paracerseis* spp. were the most important prey, whereas *C. bellicosus* and fish were important during November. The smaller spotted sand bass fed mainly on amphipods, isopods and mollusks, whereas the largest bass fed on crabs and *Octopus* spp. No trophic overlap was found between size-intervals of spotted sand bass. We concluded that *P. maculatofasciatus* are carnivorous predators that feed mainly on epibenthic invertebrates.

Resumen.—Se analizaron los hábitos alimentarios de la cabrilla arenera *Paralabrax maculatofasciatus,* en Laguna Ojo de Liebre, B.C.S., México. Las presas más importantes fueron: el anfipodos *Corophium* spp., isopodos *Paracerceis* spp., poliquetos *Pherusa* spp., jaibas *Callinectes bellicosus* y peces. Se observaron variaciones temporales en el espectro de la cabrilla arenera. Las presas más importantes en Mayo-Septiembre fueron: *Corophium* spp. y *Paracerceis* spp; mientras que en Noviembre fueron *C. bellicosus* y peces. Las cabrillas más pequeñas se alimentan principalmente de anfípodos, isopodos y micromoluscos; mientras que las más grandes se alimentan de *C. bellicosus,* peces y *Octopus* spp. No hubo traslapamiento trófico entre las clases de talla de cabrilla arenera. Se concluyo que la cabrilla arenera es un depredador bentónico que tiene un espectro alimentario muy diverso el cual esta compuesto de pequeños invertebrados y peces.

Members of the Serranidae (sea basses) inhabit tropical and temperate areas in the continental shelf, from the shallows to moderate depths. A total 47 species (18 genera) of sea bass occur in the central, eastern Pacific (Heemstra 1995). One of these species is the spotted sand bass, *Paralabrax maculatofasciatus,* which is distributed from San Francisco Bay, California to Guerrero, Mexico, including the Gulf of California (Miller and Lea 1972; Heemstra 1995).

The spotted sand bass is one of the most important demersal species in northwestern Mexico. However, in spite of their abundance, it is not considered im-

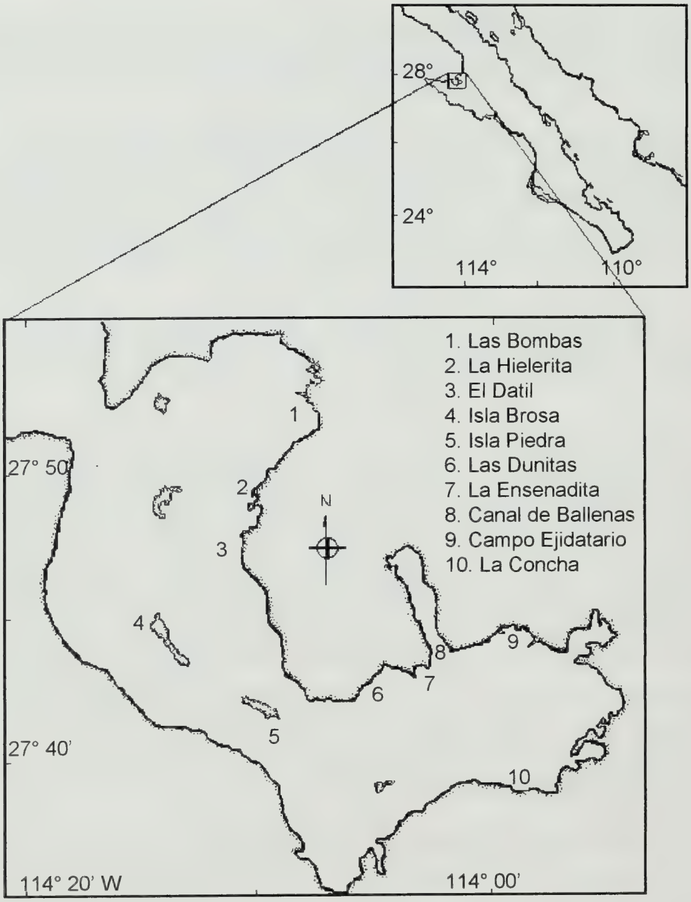
28°
24°
114°
110°
1. Las Bombas
2. La Hielerita
3. El Datil
4. Isla Brosa
5. Isla Piedra
6. Las Dunitas
7. La Ensenadita
8. Canal de Ballenas
9. Campo Ejidatario
10. La Concha
N
27° 50'
27° 40'
114° 20' W
114° 00'
1
2
3
4
5
6
7
8
9
10

Fig. 1. Study area. Laguna Ojo de Liebre, B.C.S., Mexico and sampling sites.

portant in fisheries (Lluch 1995). The spotted sand bass is a highly dominant permanent species in Laguna Ojo de Liebre, Baja California Sur, Mexico (Fig. 1). This geographical area is included in an ecological reserve named "La Reserva de la Biosfera El Vizcaino," which is the largest reserve in Mexico and one of the biggest of the world.

Several studies on feeding habits of the spotted sand bass have been done (Navarro 1985; Díaz and Soto 1988; Ferry et al. 1997; Mendoza and Rosales 2000), but not within Laguna Ojo de Liebre. Studies of the food habits of dominant fish in coastal environments are very helpful for defining the ecological relationships of these organisms with the rest of the community. Our study examined the: 1) seasonal changes in the feeding habits of spotted sand bass; and 2) ontogenetic shifts in diet based on stomach content analysis.

Material and Methods

Fish were collected in four samplings (May, July, September, and November 1995) with gill nets 140-m long, 3-m wide, and a mesh size of 9 cm. The nets were set in 10 sampling locations of the lagoon (Fig. 1). The nets were set at sunset (18:00) and recovered at sunrise (06:00). To reduce the digestive processes, the abdominal cavities of bass were injected with a solution of 10% formaldehyde neutralized with sodium borate.

In the laboratory, the prey items were identified to the lowest possible taxonomic level and recorded quantitatively, by number (N), weight (W) and frequency of occurrence (FO) (Hyslop 1980). The average weight and number of each item prey were determined. The Index of Relative Importance (IRI) of Pinkas et al. (1971) was used to determine the overall importance of each prey type. This index can also be expressed as a percentage, with higher values indicating higher importance.

$$\mathrm{IRI} = (\mathrm{W} + \mathrm{N})\mathrm{FO}$$

where IRI = index of relative importance, W = percent weight, N = percent number, and FO = percent frequency of occurrence.

Plots of cumulative prey diversity in gut contents were calculated to find the appropriate sample size by length-class and season. The sample size was considered adequate when the curve reached a horizontal asymptote (Hoffman 1978; Ferry et al. 1997).

The percentage contributions by IRI of the various dietary categories in the diets of individuals from different intervals (9.9–13, 13.1–16, 16.1–19 mm etc) were calculated.

The prey diversity in the diet is an estimation of dietary breadth (Marshall and Elliot 1997) and was calculated using Levin's standardized index (Krebs 1998):

$$\mathrm{Bi} = (1/n - 1)\left\{\left(1 \Big/ \sum_j \mathrm{P}_{ij}{}^2\right) - 1\right\}$$

where Bi = Levin's index for the predator *i*, P_{ij} = proportion of prey *j* in the diet of predator *i*, and *n* = the number of prey categories. This index ranges from 0 to 1; low values (<0.6) indicate a diet dominated by few prey items (specialist predator) and higher values (>0.6) indicate generalist diets (Krebs 1998; Labropoulou and Eleftheriou 1997).

The diet overlap between the different size-classes of spotted sand bass by season was calculated using Morisita's index (Krebs 1998):

$$\mathrm{C}\lambda = 2 \sum ({}_j\mathrm{P}_{ij}\mathrm{P}_{kj}) \Big/ \left(\sum_j \mathrm{P}_{ij}{}^2 + \sum \mathrm{P}_{kj}{}^2\right)$$

where Cλ = Morisita's index of predators *i* and *k*, and P*kj* = proportions of predator *i* and *k* with prey *j* in their stomachs. Diet overlap increases as the Morisita's index increases from 0 to 1. Overlap is generally considered biologically significant when the value exceeds 0.60 (Langton 1982).

Results

Spotted sand bass were caught during May, July, September, and November. This species is widely distributed in the lagoon mainly in sandy and muddy bottoms (Acevedo 1998). A total of 151 fish were caught with an average standard length (SL) of 17.35 cm ± 5.16 cm (standard deviation) and an average weight

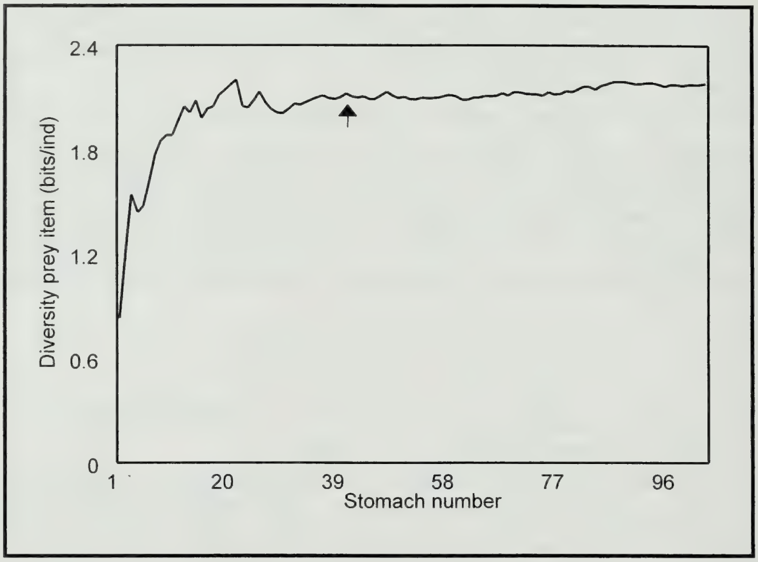

Fig. 2. Randomized cumulative prey curve for all fish with gut contents analyzed.

of 97.8 g ± 11.9. Of the total stomachs analyzed, 109 contained food (72%) and 42 were empty (28%).

The 109 stomachs with food were sufficient to describe global spectrum of the spotted sand bass according to the methodology proposed by Hoffman (1978) and Ferry et al. (1997). We used the same strategy to determine the sample size by season (except in November, because we sampled only two stomachs) and by size intervals. All the subsamples were representative of the spotted sand bass diet (Fig. 2).

Thirty-three food components were identified. Benthic invertebrates dominated the diet of spotted sand bass. By number of organisms, 53% were amphipods (*Corophium* spp.) 17% isopods (*Paracerceis* spp.), and 7%. polychaetes (*Pherusa* spp.). The rest of the food components had low values (<5%) (Fig. 3). The average number of food components in each stomach was 2.5 ± 5.

The most important prey by weight was the warrior swimcrab *Callinectes bellicosus* (30%), followed by the fish *Hypsoblennius* spp. (17%), the amphipods *Corophium* spp. (10%) and polychaetes *Pherusa* spp. (9%). The amphipods *Corophium* spp. (46%), the polychaetes *Pherusa* spp. (29%) and the isopods *Paracerceis* spp. (28%) dominated in frequency of percentage occurrence (Fig. 3).

According to IRI, amphipods *Corophium* spp. (66%), isopods *Paracerceis* spp. (12%), polychaetes *Pherusa* spp. (11%) and warrior swimcrab *C. bellicosus* (5%) were the most important food components (Table 1).

Relative importance of several prey varied seasonally (Fig. 4). During May, July, and September (spring-summer), the amphipods *Corophium* spp., the isopods *Paracerceis* spp. and the polychaetes *Pherusa* spp. were the most common invertebrates in the diet. In November (winter), the warrior swimcrab, the fish *Hypsoblennius* spp., the *Octopus* spp. and *Nassarius* spp. were the most important prey.

We analyzed five size-classes (9.9–34.6 cm SL) with intervals of 3.0 cm. In

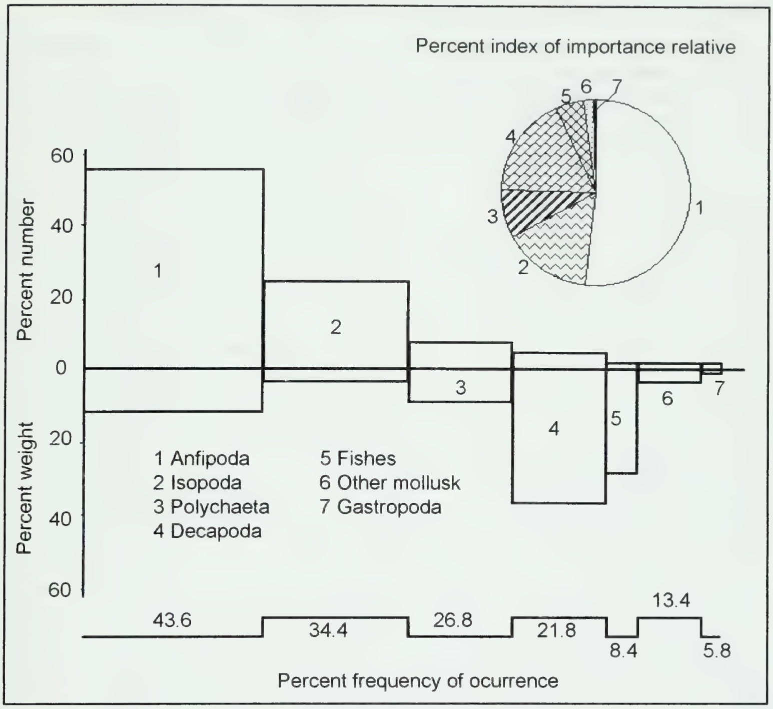

Fig. 3. The major prey species found in the stomach of spotted sand bass *Paralabrax maculatofasciatus* presented as percent of number of individuals, weight, frequency of occurrence, and index of relative importance.

the diet of spotted sand bass, the prey with reduced mobility, such as the benthic amphipods and gastropods, were more common in the diet of the small fish (<25 cm SL). The largest spotted sand bass (>25 cm SL) feed on larger prey with faster movements such as warrior swimcrab and fish (Fig. 5).

The low values of Levin's index (Bi) by each size category (between 0 to 0.52), indicated that spotted sand bass could be categorized as specialist in their feeding habits. The small and large spotted sand bass had higher specialization degree and the medium size had a lower specialization degree (Fig. 6).

In global analysis, dietary overlap values between size classes were high. The most evident were between the size classes 1–2 ($\lambda = 0.85$), 1–4 ($\lambda = 0.86$), 2–3 ($\lambda = 0.83$), 2–4 ($\lambda = 0.84$). However, in seasonal analyses we don't find significant evidence for dietary overlap (values less than 60%) according to methodology's Langton (1982).

Discussion

We found a considerable number of food components within the trophic spectrum of the spotted sand bass (33 food components). However few prey of the benthic habitat were dominant within their diet. Ferry et al. (1997) also noted that spotted sand bass, like many other serranids, is a generalist feeder. Other studies have recorded that decapods and fish were the major components in the diet of the spotted sand bass (Navarro 1985; Díaz and Soto 1988; Cruz-Escalona 1998).

Table 1. Summary of food categories in stomach contents of spotted sand bass from Laguna Ojo de Liebre, B.C.S., Mexico, expressed as percentages based on number (%N), weight (%W), frequency of occurrence (FO) and index of relative importance (IRI).

Prey	%N	%W	%FO	%IRI
Crustacea				
Callinectes bellicosus	1.41	31.27	6.42	4.76
Sicyonia spp.	0.85	1.88	3.67	0.23
Penaeus spp.	1.27	0.32	6.42	0.23
Solenocera spp.	0.14	0.53	0.92	0.01
Squilla spp.	0.28	0.01	0.92	0.01
Majidae	0.14	0.09	0.92	<0.001
Corophium spp.	51.90	10.23	45.87	64.65
Califanthura spp.	0.56	0.02	1.83	0.02
Paracerceis spp.	16.78	1.82	28.44	12.00
Cirolana spp.	4.37	0.53	9.17	1.02
Shrimp (unidentifiable).	0.14	0.15	0.92	0.01
Brachyuran crabs (unidentifiable)	1.83	0.07	3.67	0.16
Crustacean remains (unidentifiable)	0.14	3.63	11.93	1.02
Pignogonida	0.14	0.02	0.92	<0.001
Anellida				
Pherusa spp.	7.19	9.22	29.36	10.93
Mollusca				
Polyplacophora	2.12	0.22	10.09	0.53
Pelecypoda	2.54	4.31	14.68	2.28
Nassarius spp.	1.13	0.51	5.50	0.20
Fisurella spp.	1.41	0.82	0.92	0.05
Solemya valvulus	0.42	0.40	2.75	0.05
Tagelus spp.	0.14	0.89	0.92	0.02
Octopus spp.	0.28	2.17	1.83	0.10
Bivalve remains (unidentifiable)	0.28	0.53	1.83	0.03
Mollusca remains (unidentifiable)	0.14	1.03	1.83	0.05
Osteichthyes				
Hypsoblennius spp.	0.14	17.33	0.92	0.36
Gerreidae	0.14	4.09	0.92	0.09
Diplectrum spp.	0.28	0.73	1.83	0.04
Ilypnus gilberti	0.14	0.54	0.92	0.01
Syngnathus leptorhynchus	0.14	0.05	0.92	<0.001
Fish remains (unidentifiable)	1.13	1.22	2.75	0.15
Echinodermata				
Ophiactis savignyi	0.14	0.01	0.92	<0.001
Other items	2.26	5.37	5.50	0.95

Spotted sand bass are distributed widely in Laguna Ojo de Liebre; however they are most abundant in areas with eelgrass (*Zoostera marina*). In this environment, the presence of isopods, amphipods, and mollusks are common (Orth 1977; Main 1985; Dielh 1992). These groups, not surprisingly, turned out to be the most important components in the trophic spectrum of the spotted sand bass. Larger size prey such as the warrior swimcrab *C. bellicosus* and fish that were important to larger spotted sand bass are also found in these eelgrass beds.

The high incidence of benthic prey in the diet of *P. maculatofasciatus* also has

Table 2. Diet overlap between size-classes of spotted sand bass *Paralabrax maculatofasciatus* from Laguna Ojo de Liebre, B.C.S., Mexico.

Size-class	(9.9–13)	(13.1–16)	(16.1–19)	(19.1–22)	(>22.1)
May					
(9.9–13)	1				
(13.1–16)	0.40	1			
(16.1–19)	0.24	0.17	1		
(19.1–22)	0.36	0.15	0.2	1	
(>22.1)	0.05	0.02	0.16	0.05	1
July					
(9.9–13)	1				
(13.1–16)	0.29	1			
(16.1–19)	0.03	0.07	1		
(19.1–22)	0.31	0.05	0.00	1	
(>22.1)	0.29	0.59	0.00	0.32	1
September					
(9.9–13)	1				
(13.1–16)	0	1			
(16.1–19)	0.05	0	1		
(19.1–22)	0	0	0	1	
(>22.1)	0	0	0	0	1
November					
(9.9–13)	1				
(13.1–16)	0	1			
(16.1–19)	0	0	1		
(19.1–22)	0	0	0	1	
(>22.1)	0	0	0	0	1

been reported in other localities. Mendoza and Rosales (2000) indicated that the spotted sand bass at Punta Banda, Baja California feed basically on amphipods, isopods, and fish. However in a seasonal analysis he found that the dominance of the amphipod *Corophium* spp. is higher during summer, whereas in winter, the fish *Atherinops affinis* and *Sardinops sagax* were the most important.

In Laguna Ojo de Liebre spotted sand bass also showed seasonal dietary changes; during May–September feeding mainly on small prey, and in November fed on larger prey. Other authors (Ferry et al. 1997; Cruz-Escalona 1998) also have reported these seasonal variations. It is presumed that this change is because of seasonal changes in the availability of prey.

Our analysis of different size classes indicated that spotted sand bass change diet ontogenetically. Less mobile prey, including benthic amphipods, isopods, and polychaetes, were proportionately more important in the diet of small spotted sand bass, suggesting that smaller fish are less capable of catching more mobile prey. Roberts et al. (1984) noted that mysids and amphipods were more dominant in the diet of the smaller (<240 mm) barred sand basses *Paralabrax nebulifer*. However, they also found that prey such as gastropods and polychaetes were most abundant in larger barred sand bass.

The ontogenetic changes in the diet represent ecological mechanisms, and reflect the low ability of small predators to efficiently capture certain prey (Chao

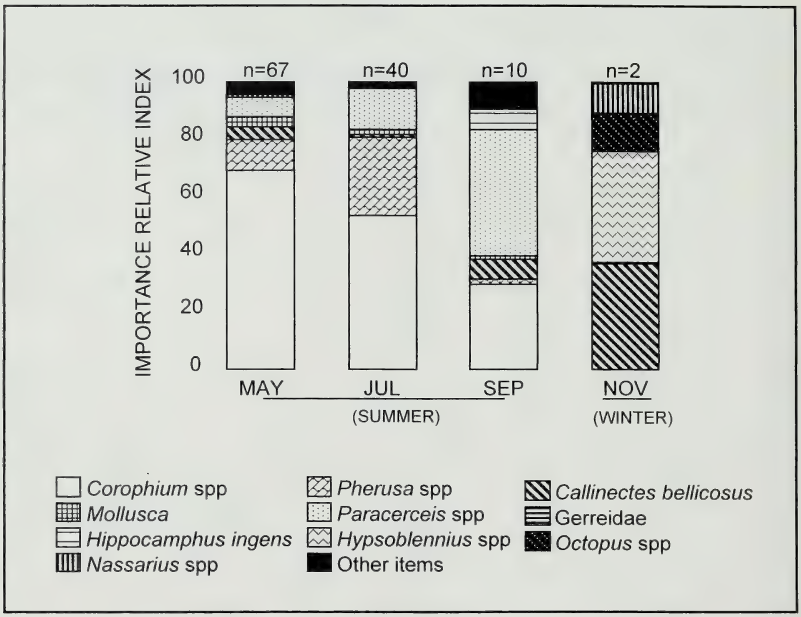

Fig. 4. Seasonal variation of the major prey species in the diet of spotted sand bass *Paralabrax maculatofasciatus* determined by index of relative importance (IRI).

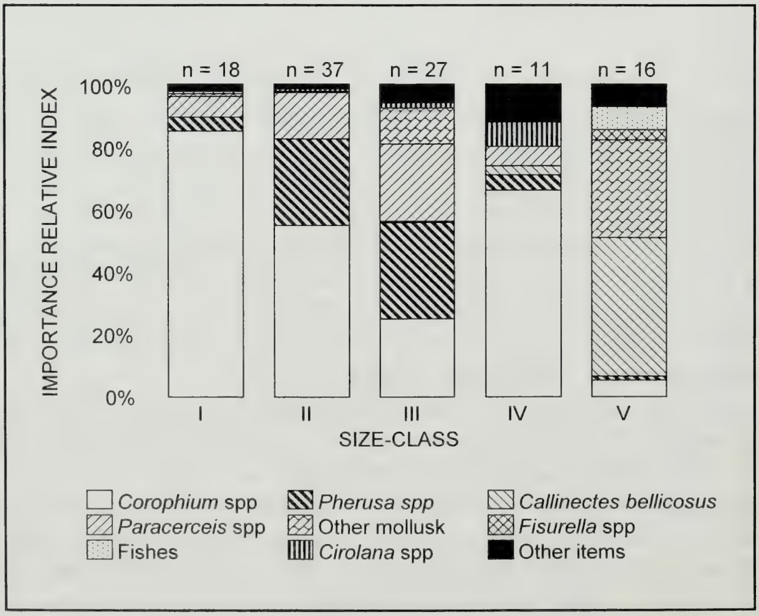

Fig. 5. Percentage contribution of the most important food item for index of relative importance of the gut contents found in 151 *Paralabrax maculatofasciatus* individuals collected. Each bar represent a fish size class.

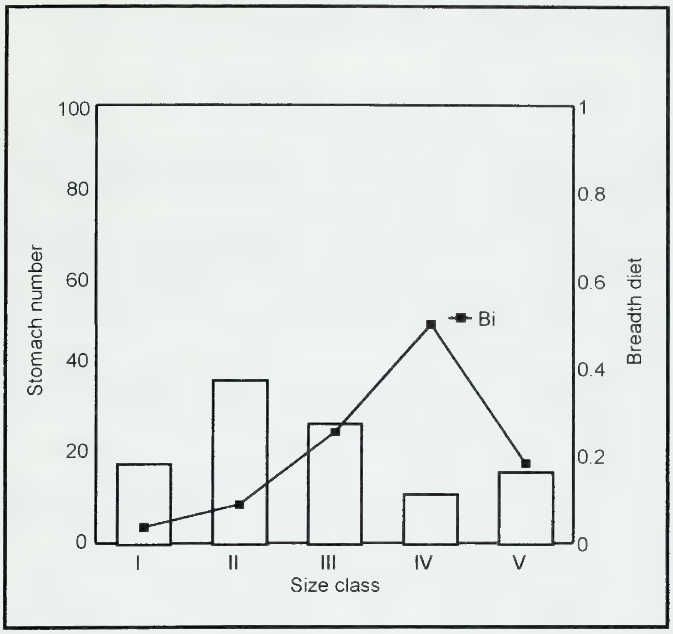

Fig. 6. Diet breadth of *Paralabrax maculatofasciatus* according to Levin's index.

and Musick 1977; Sumpton and Greenwood 1990). In many situations the smaller fish had not developed certain physical mechanisms (ability to break calcareous structures) or physiological (enzymatic processes) to feed adequately on some prey with high availability (Gerking 1994).

We found that spotted sand bass present two feeding behaviors; small and large fish have a specialization behavior, while the medium size spotted sand bass had a generalist strategy. Spotted sand bass, as other serranids, possess structures useful to catch and process a wide diversity of prey items (Pickett and Pawson 1994). Ferry et al. (1997) found a sharply toothed premaxilla, mandible, vomer, and palatine, as well as fine-toothed gill arches and pharyngeal jaws. This might explain the wide prey spectrum found in different-sized spotted sand bass. Gerking (1994), defined this capacity of change as "trophic plasticity."

The low values of overlap between successive length classes of *P. maculatofasciatus* attest to the gradual changes in diet of this species throughout their life. The high prey diversity in the diet of spotted sand bass would explain the lower overlap values obtained. Wootton (1990) indicates that changes by age in the use of habitat is an important factor in the food preference of each fish species, because the age implies a food or habitat partitioning between several size-classes from the same species.

Acknowledgments

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First Specimens of the Fangjaw Eel *Echiophis brunneus* (Pisces: Ophichthidae) from the Gulf of California, México

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The fangjaw eel was first referred to by McCosker (1977) as an undescribed ophichthid species of the genus *Echiophis* Kaup 1856, with a potential distribution from the Gulf of California to Panama. Castro-Aguirre and Suárez de los Cobos (1983) described this ophichthid fish as a new genus and species (*Notophtophis brunneus*) on the basis of a specimen collected in Bahía de Acapulco, Guerrero, México. McCosker et al. (1989) reassigned this new taxon into the known genus *Echiophis,* which contains five nominal species in the Atlantic and one or two species in the eastern Pacific.

Echiophis brunneus (Castro-Aguirre & Suárez de los Cobos 1983), also known as "Pacific spoon-nose eel," is a benthic fish that reaches 1.4 m in length and inhabits shallow coastal waters with sandy and muddy bottoms (McCosker and Rosenblatt 1995). Although many bio-ecological aspects of this species are unknown, it is commonly found in the stomach contents of scalloped hammerhead, *Sphyrna lewini,* from southern Sinaloa (J.L. Castro-Aguirre, pers. obs.).

The northernmost collection report of *E. brunneus* in the vicinity of the mouth of Río Presidio, southern Sinaloa, México (Amezcua-Linares 1996) is considered invalid, because it was based on an erroneous identification of specimens of *Cynoponticus coniceps* (Castro-Aguirre et al. 1999). Therefore, the presence of *E. brunneus* in the Gulf of California has not been previously confirmed with voucher specimens.

Two specimens of *E. brunneus* (Fig. 1) were captured with a commercial shrimp net on 19 January 1999 near El Desemboque, Sonora, between Santo Tomás and Cabo Tepoca, upper Gulf of California (30° 34′ N, 113° 01′ W). Both specimens were taken at a depth of 33 m on a sandy bottom. Our specimens of *E. brunneus* confirm the occurrence of this ophichthid eel in the Sea of Cortez zoogeographical province (*sensu* Briggs 1974; Thomson et al. 2000).

The specimens of fangjaw eel were identified using the following combination of diagnostic characteristics (Castro-Aguirre and Suárez de los Cobos 1983; Allen and Robertson 1994): body elongated, cylindrical, pointed at both ends; tail longer than head and trunk; pectoral fins present; gill opening relatively elongate, vertical and lateral; snout short, subconical, slightly constricted near tip; teeth very strong and pointed, biserial, largest anteriorly on jaws; body overall tan with abundant small, brown spots on back and sides; and dorsal fin brown. A very large canine

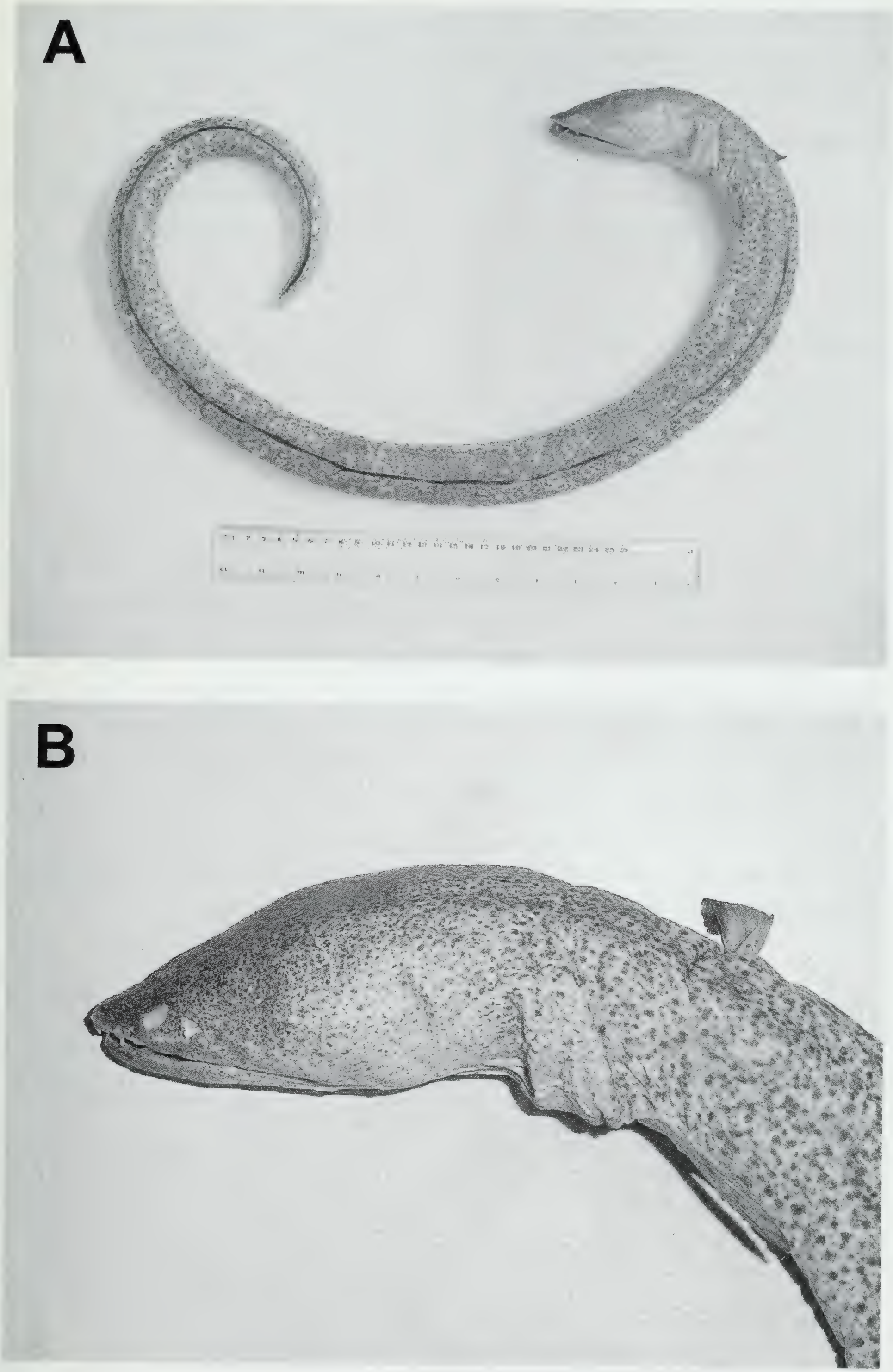

Fig. 1. A) Fangjaw eel, *Echiophis brunneus,* UABC-0960, 995 mm TL, collected in El Desemboque, Gulf of California, México, on 19 January 1999. B) Lateral view of the head region of the same specimen. Photographs by Gorgonio Ruiz-Campos.

tooth inserted on the distal part of the vomer is considered diagnostic for specific identification; however, one of the examined specimens showed two canine teeth.

Morphometry of the two collected specimens was based on Castro-Aguirre and Suárez de los Cobos (1983). The body measurements in millimeters of the two specimens are as follows: total length (TL) (862 and 995); distance from tip of snout to: origin of anal fin (425 and 428), anus (418 and 422), origin of dorsal fin (152 and 155), axilla of pectoral fin (114 and 115), and gill opening (102 and 101); maximum head width (42.4 and 43.7), maximum head depth (44.7 and 42.0), width of mouth (32.7 and 35.7), maxillar length (53.6 and 52.8), mandible length (52.1 and 52.4), snout length (15.4 and 13.9), maximum interorbital width (13.2 and 14.4), minimum interorbital width (11.2 and 10.7), horizontal ocular diameter (8.8 and 9.3), distance from tip of snout to anterior (10.7 and 9.8) and posterior nostril (12.8 and 10.9), and internostril space (2.7 and 2.3).

The coloration of the specimens as preserved in alcohol is dark brown on back, and light brown below. Faint reticulations and small black round spots spread along the dorsum and sides of the trunk and tail. The dorsal fin base has a black margin, and the mouth cavity is white-cream and pinkish on the pharyngeal region.

The specimens are deposited in the Fish Collections of the Facultad de Ciencias, Universidad Autónoma de Baja California (UABC-0960) and Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional (CICIMAR-CI 4793).

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Observations on nesting seabirds and insular rodents in the Middle Sea of Cortés in 1999 and 2000

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The Sea of Cortés has been touted as an area of great biological diversity. However, much of the information on the biota of this area comes from single visits, often several decades old, and frequently the data is transmitted only verbally or in a generic sense. Regretably, although a number of scientists conduct research in the area, little information has been published. As a result, our ability to determine the temporal or spatial changes in the populations of the native species of this area, and the negative impacts of human activities is limited.

General survey data of homeotherms helps to document and understand changes in size of populations or shifts in their distribution, and can be especially important when the most recent published data is at least several decades old. In this spirit we present our observations from three cruises to the Middle Sea of Cortés in 1999 and 2000.

These cruises were 5–17 April 1999, 19–30 October 1999, and 6–19 April 2000, and were made aboard the Enchantress, a 49-ft Florida ketch, under the sponsorship of The Kelton Foundation. The locations visited are shown in figure 1, and the intineraries were:

April 1999: La Paz, Los Islotes, Isla Partida (Ensenada Grande), Isla San José (Punta Colorada), Puerto del Gato, Timbabichi, Isla Monserrat (SW end), Isla Carmen (Punta Baja), San Juanico, San Ildefonso, Farallón de San Ignacio, Isla Cerralvo, Isla Espíritu Santo (El Candelero), La Paz.

October 1999: La Paz, Isla San Francisco, Isla Habana, Isla Morena, Roca Negra, Puerto del Gato, Roca Marcial, Montserrat, Isla Las Galeras, Puerto Escondido, Isla Los Coronados, Bahía Siquicismunde, Isla San Ildefonso, Bahía Coyote, Isla Santa Inés, Isla Tortuga, Santa Rosalía.

April 2000: La Paz, Roca Marcial, Isla Cholla, Los Coronado, San Juanico, San Ildefonso, Bahía de Santo Domingo, Bahía Coyote, Punta Chivato, San Marcos (southern tip), Santa Rosalía, Tortuga, San Pedro Mártir, Bahía San Pedro, San Pedro Nolasco, San Carlos, Farallón de San Ignacio, Espíritu Santo, La Paz.

During these cruises we made observations on all homeotherms encountered; we surveyed several islands used for breeding by seabirds, and set rodent traps on 5 islands. Most navigation was diurnal, and we carried out observations throughout the day. On those occasions that navigation was nocturnal we made few observations. Herein we report on the nesting seabirds and insular rodents. Our objective in this note is to provide our data, rather than make detailed analysis, and we restrict literature coverage to a minimum.

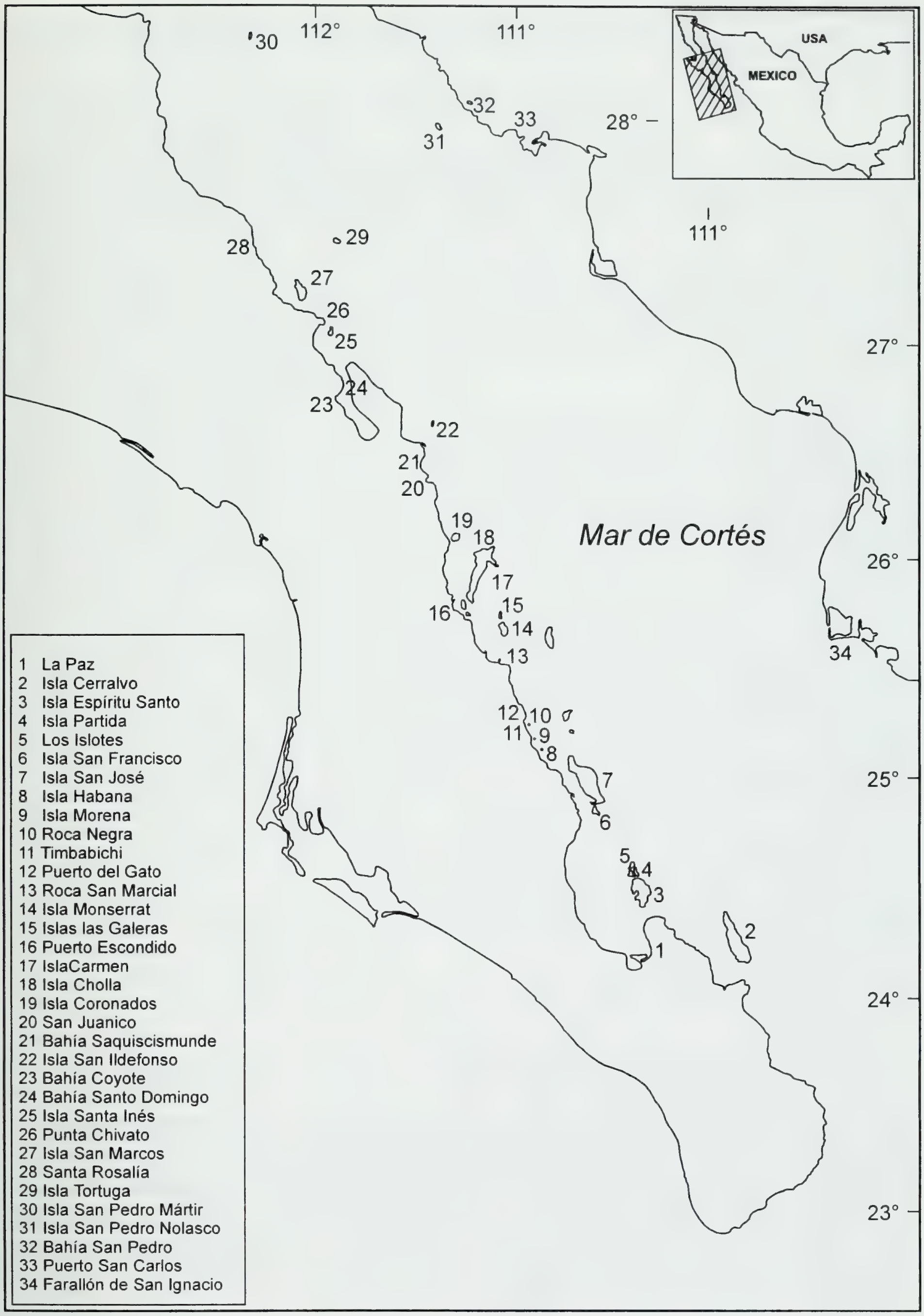
112°
111°
111°
28°
27°
26°
25°
24°
23°
USA
MEXICO
Mar de Cortés
1 La Paz
2 Isla Cerralvo
3 Isla Espíritu Santo
4 Isla Partida
5 Los Islotes
6 Isla San Francisco
7 Isla San José
8 Isla Habana
9 Isla Morena
10 Roca Negra
11 Timbabichi
12 Puerto del Gato
13 Roca San Marcial
14 Isla Monserrat
15 Islas las Galeras
16 Puerto Escondido
17 IslaCarmen
18 Isla Cholla
19 Isla Coronados
20 San Juanico
21 Bahía Saquiscismunde
22 Isla San Ildefonso
23 Bahía Coyote
24 Bahía Santo Domingo
25 Isla Santa Inés
26 Punta Chivato
27 Isla San Marcos
28 Santa Rosalía
29 Isla Tortuga
30 Isla San Pedro Mártir
31 Isla San Pedro Nolasco
32 Bahía San Pedro
33 Puerto San Carlos
34 Farallón de San Ignacio

Fig. 1. Central and southern Sea of Cortés showing the locations mentioned in the text.

Table 1. Nesting localities of nesting seabirds in the Sea of Cortés in April 1999 and 2000. A "X" represents confirmed nesting, "?" possible nesting, "No" (in San Ildefonso) the notable lack of this former species' colony.

	Magnificent Frigatebird	Red-billed Tropicbird	Brown Pelican	Brown Booby	Blue-footed Booby	Double-crested Cormorant	Heermann's Gull	Yellow-legged Gull
Cerralvo			X					?
Ballena			X					X
Gallo								X
Gallina								X
Roca Monumento								?
Los Islotes					X			X
Las Ánimas			X					X
Roca San Marcial							X	X
Roca Solitaria								X
San Damián								X
Monserrat								?
Las Galeras (both)								X
Isla Cholla								X
Unnamed, SW Coronado								X
San Ildefonso				X	X	X	No	X
Bahía Coyote								
Guapa								X
Blanca								X
Pitaya								X
San Ramón			X					X
Liebre								X
Coyote + its rocks								X
Tecomate								X
San Marcos								X
Tortuga			X	X	X			X
San Pedro Mátrir		X	X	X	X			X
San Pedro Nolasco	?		X	X	?			?
Farallón de San Ignacio		X		X	X	X	X	?

Sea Birds

On small islands or restricted populations where we could count all nests (or adults sitting on nests) without disturbing the birds, we did so. Brown pelicans are very sensitive to human intrusion, and, therefore, even on small islands we did not count them. On large islands we obtained counts or estimates on the minimum number of nesting pairs. Our counts of larger colonies from the vessel are likely to have been very limited. We did not search for crevice-nesting birds, so except for the Red-tailed Tropicbird, we restricted ourselves to seabirds that nest on the surface. The summary of nesting species per island is presented in table 1. The species accounts follow:

Fregata magnificens. Magnificent Frigatebird.

This species was common throughout the area covered on all three cruises, but only in April 2000 did we observe some individuals that could be nesting. On San Pedro Nolasco there were about 50 on a bush, including some males with evident gular pouch. We did not land on the island to verify whether they were nesting.

Phaethon aethereus. Red-billed Tropicbird.

In April 1999 we saw at least 12 flying over Farallón de San Ignacio. This species had not been reported to nest on this island (Everett and Anderson 1991), but was recently documented to do so in large numbers (González-Bernal et al. submitted).

In April 2000 we saw 2 on San Pedro Mártir, one of which seemed to be nesting (laying in a crevice). This island harbors a large nesting population of this species (Everett and Anderson 1991, Tershy and Breese 1997).

Pelecanus occidentalis. Brown Pelican.

Brown Pelicans nest on many islands in the Sea of Cortés (Everett and Anderson 1991). In April 1999 we recorded them breeding on Las Ánimas. (62 nests, but there could be up to 10 more on the NW end), Isla San Ildefonso (between 1000–3000 nests), Southern end of the eastern shore of Isla Cerralvo (a few decidedly on nests, but we were to far away to count them), and Isla Ballena (several hundreds).

On las Ánimas one nest had 2 eggs, and one 2 small chicks, whereas in San Ildefonso the few nests that we examined (with binoculars, from a ridge) contained from eggs to gray-colored juveniles. Nests on the southern end of this island seemed to have smaller chicks than nests on the western side. On Ballena there were chicks of all sizes. Those on the western side of the island were overally larger than those on the eastern side, suggesting that this was the order of colony formation.

In April 2000 Brown Pelicans were nesting abundantly on San Ildefonso, Tortuga (thousands), San Pedro Mártir (at least hundreds; 2000–3000 pairs were estimated in the early 1990s—Tershy and Breese 1997), San Pedro Nolasco (thousands), and San Ramón in Bahía Coyote (40 nests). Large chicks were present on Tortuga and San Pedro Nolasco.

During non-breeding season, in October 1999 pelicans were rather scant, except in Bahía Coyote, were we saw over 220 (vs. about 150 in the entire rest of the trip).

Sula leucogaster. Brown Booby.

Isla San Ildefonso has been a traditional nesting ground for this species (Mellink 2000), and, in both years there were several hundred nests there, especially in the SW area of the island, along with nests of blue-footed Boobies. Pairs varied from building nests to having 50-days old chicks, suggesting the onset of egg-laying in early-mid January. Several nests had two large chicks. In October 1999 there were less than 100 individuals on San Ildefonso and no breeding evidence. Three juveniles were still being fed by their mothers. One of the juveniles had fishing line coming out of its beak.

In April 2000 Brown Boobies nested abundantly on San Pedro Mártir, where there were several thousands, although we thought not as many as the 74,000 pairs estimated in 1990 (Tershy and Breese 1997). There were surprisingly few on Tortuga and San Pedro Nolasco. On the first of these two islands we counted

20, on ledges on the southern cliffs (also used by Blue-footed Boobies), 5 of which sat on nests. On San Pedro Nolasco there were 50–60 individuals, and only 11 apparently nesting. We did not land to examine these presumed nests.

On Farallón de San Ignacio we estimated "thousands" in April of both years, and detailed counts in March 2001 recorded about 1200 pairs nesting (González-Bernal et al. submitted). In 1999 most of them were at the protected eastern face of the rock, and on the top of the cliff there were several individuals that appeared to be incubating or tending chicks, but we failed to see any chicks. However, the sea was too rough for proper observation of the birds. Rough seas also precluded landing on both occasions. In April 1999 several juveniles were flying in the area, suggesting that there may have been breeding in the fall.

Sula nebouxii. Blue-footed Booby.

In April 1999 we found Blue-footed Boobies nesting on Los Islotes (2 empty nests, but a female sitting on one of them, suggesting that laying was about to start). On Isla San Ildefonso there were several hundred nests, although fewer than those of Brown Boobies, in the same area of the latter. Individuals varied from courtship to tending large 50-day chicks, setting the onset of egg-laying in early-mid January. In October 1999 there were a few hundred adults on San Ildefonso, and one pair, perhaps two, appeared to perform courtship displays.

In April 2000 this species was nesting at several places; several hundred on San Ildefonso, thousands on Tortuga, mostly on the southern cliffs where some were obviously on nests. Many were nesting on San Pedro Mártir. Here they had from eggs to large chicks. There seemed to be much less than the 110,000 pairs estimated in 1990 (Tershy and Breese 1997). There were several hundreds on San Pedro Nolasco. Some were sitting on the ground but it was not clear if they were on nests. During both years there were many flying about Farallón de San Ignacio, but we could not confirm nesting, although such was confirmed in 2001 (González-Bernal et al. submitted).

Phalacrocorax auritus. Double-crested Cormorant.

Double-crested Cormorants were noted in small numbers on many places along the cruise, but breeding evidence was scant. San Ildefonso is a known breeding locale for this species (Everett and Anderson 1990), but we could not find any nesting birds in any of the two years (perhaps because of our avoidance of the areas occupied by nesting pelicans). However, in October 1999 4 out of 7 adults had nuptial plumes, and one mummified chick confirmed that nesting had occured on the island during the previous nesting season. In April 2000 they were nesting on San Pedro Nolasco, where we counted, from the vessel, 15 nests, some of which held large chicks.

Larus heermannii. Heermann's Gull.

There was a breeding colony on Roca San Marcial, both years. In April 1999 there were about 500 individuals, including adults and juveniles. They were beginning to nest, and we counted 34 nests with 1 egg, and 2 with 2 eggs. One pair was courting. We found twelve nests and 2 adults that had been predated upon; the adults probably by Peregrine Falcons (*Falco peregrinus*), a known predator of the species (Velarde 1993). In April 2000 there were 200 birds, of which 81 were on nests. We examined 17 nests: 12 had 1 egg, and 5 had 2 eggs. Heermann's Gulls were absent from this island in October 1999.

Isla San Ildefonso had been a traditional nesting site for this gull (Mellink 2001). However, in April 1999 and April 2000 there was clearly no nesting by this species (see also Mellink 2001). In April 1999 there were a few dozen birds at Farallón de San Ignacio, and in April 2000 we found evidence of their nesting here. There were between 20 and 40 adults sitting in nesting position on low rocks off the southeastern edge of the island, and one nest checked from a distance had eggs (see also González-Bernal et al. submitted, and Mellink 2001).

Larus livens. Yellow-legged Gull.

In both years we found this species nesting profusely, or presumed its nesting, on islands in the area (Table 1). In 1999 we examined 109 nests, scattered among islands along our survey path: 44 contained one egg, 27 two eggs, 36 three eggs, and 2 four eggs. In 2000 we examined the nests only sufficiently to confirm nesting, but did not note their contents in detail.

On Las Galeras, in April 1999, on the NW islet the nests were at the western side. At the NE islet they were on the entire islet, but those at the SW side had 4 eggs. From this area the number of eggs in nests decreased toward the NE side, where nests had only 1 egg. This progression suggests the order of colony formation.

On the SE islet of Las Galeras we collected a pile of bones, apparently regurgitated. It contained pre-opercula of serranid fishes (Jorge Domínguez, CICESE). On Isla Cholla there is a fishermen's hut. As we suspected that fishermen might have been consuming gull eggs, in April 1999, we examined their trash dump. We found shells only of domestic fowl's eggs.

In October 1999 the species was widespread.

Rodents

To survey the rodents, we used Sherman live-traps baited with oat flakes and natural vainilla extract. A single night in October of 1999, was devoted to each site. All rodents captured were examined, identified and released on the spot. On Isla San Ildefonso (80 traps, 25–26 October) and southern Isla Santa Inés (40 traps, 28–29 October) we did not capture any rodents. In no instance did we capture introduced species.

Isla Los Coronados

We surveyed rodents on Isla Los Coronados on 23–24 October through 40 traps placed in the sandy spit on its southern end, and 40 on the rocky volcanic outcrops adjacent to it. We trapped two species.

Chaetodipus spinatus pullus. 13 females, 9 males, 1 unsexed. They occurred principally in the sand spit, but a few also in the rocky area. Soil workings by this species in the sand spit were extensive.

Peromyscus pseudocrinitus. 5 females, one of them pregnant, 10 males, 1 unsexed. Unlike Álvarez-Castañeda (1998), who found the species more common in the sandy area, we found it restricted to the rocky outcrops. It is posible that a current increase in the population of pocket mouse has caused this restriction.

The trapping success attained in this study contrasts sharply with the findings of Smith et al. (1993) who, during 249 night-traps in the southern area (roughly the same spot we used) caught only 1 pocket mouse. We did not see any evidence of current existence of feral cats on the island, although our search effort was insufficient to address this conclusively.

Coincident with Smith et al.'s findings, there was no sign suggesting that *Neotoma bunckeri* could still be extant, although our efforts were largely insufficient to address this issue. These authors contended that the extinction of this packrat had been brought about by the removal of ironwood (*Olneya tesota*) for fuel, and the introduction of domestic cats. Based on our experience with packrat ecology and conservation problems elsewhere, we feel that introduction of cats would have been sufficient to have caused their demise on this island, and that, in the absence of cats, the impact of firewood removal would not have been critical to the packrats.

Isla Tortuga

On 29–30 October, 80 traps were set in the most vegetated area high on the northwestern section (27°26′34″N, 111°53′41″W). We trapped one species.

Peromyscus dickeyi. 5 females (1 pregnant, 2 recently lactated, 1 inactive, 1 juvenile), 2 males (1 with abdominal testes, 1 juvenile). In 1997 Álvarez-Castañeda and Cortés-Calva (1999) had a 9% trapping success of this species; identical to that found by us. Their trapping location was not given.

Isla Coyote

On Isla Coyote, Bahía Coyote, inside Bahía de Concepción (27–28 October), from which no native rodents have been reported, we placed 80 traps on top of the central ridge of the island. We captured one mouse.

Chaetodipus spinatus, unknown ssp. One postlactant female. There are some pocket mouse workings in the area were she was caught, but this seem to be the only suitable area for them on the island. Therefore, the population should be very reduced.

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Macroparasites of Pacific sanddab *Citharichthys sordidus* (Bothidae) from polluted waters of the Palos Verdes Shelf, southern California

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Pacific sanddab *Citharichthys sordidus* Girard is very abundant along the Pacific coast of North America and is an important food fish in California (Hopkins 1986). It is a major component of trawl-caught fish in many locations in the Southern California Bight (SCB) (Allen et al. 1999). Pacific sanddab inhabits polluted waters off the coast of southern California where it associates with bottom sediments that contain a variety of contaminants like dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) as well as heavy metals (Eganhouse and Venkatesan 1993).

More than a hundred papers have demonstrated a correlation between parasitism and pollution in marine fish (Khan and Thulin 1991). There is an enormous variation in responses of different parasite taxa to different types of pollution resulting in increased or decreased parasitism (Mackenzie 1999). Pollutants may lower resistance of fish to parasites or increase the density of animals that transmit parasites to fish (Eiras 1987, Khan and Kiceniuk 1988). Decreased parasitism, on the other hand, can result from direct or indirect toxicity effects on parasites. Changes in densities of invertebrate hosts can also lead to decreased parasitism in fish (Lafferty 1997). The fact that environmental changes can affect parasites in so many ways suggest that data on parasitized fish that are impacted by pollution may be useful as a more sensitive indicator of changes in aquatic environments.

Although much is known about the life history of Pacific sanddab (Arora 1951; Rackowski and Pikitch 1989), little is known about the relationship between pollution and parasitism in this fish host. Previously, Love and Moser (1983) reported 8 parasite species infecting Pacific sanddab. The present study focuses on the population of Pacific sanddab that occupies the waters off White Point, part of the Palos Verdes Shelf (PVS). Here the sediments contain high concentrations of contaminants that can bioaccumulate in the tissues of this fish (McDermott-Ehrlich et al. 1978). Historically, the tissues of PVS fishes exhibit some of the highest levels of DDT in the nation (Mearns et al. 1988). The purpose of this study is to report on the prevalence and intensity of ecto- and endoparasites of Pacific sanddab from the highly polluted waters of the PVS. The effect of seasonality and host age on parasitism was also examined.

Materials and Methods

A total of 137 Pacific sanddab was obtained from otter trawls of the research vessel Vantuna (owned and operated by Occidental College, Eagle Rock, California). Bottom trawls for fish off White Point (33°43′N, 118°19′W) ranged in depth from 91 to 110 m. Sanddab were collected during August 1997, October

1997, February 1998, and April 1998. Fish were transported to the laboratory where they were measured (mm) and otoliths were removed for aging. Otoliths were either sectioned using the techniques of Love et al. (1984) or sanded, and visible growth annuli were counted.

Fish samples were preserved using the quick-freezing technique of Bush and Holmes (1986) and later thawed and necropsied. Organs examined for parasites were gills, heart, liver, gallbladder, spleen, muscle, and gastrointestinal tract. Parasites found were sorted into major taxonomic groups, cleaned, counted, and fixed. Digenea, Monogenea, Cestoidea, and Acanthocephala were fixed in AFA (ethyl alcohol-formalin-acetic acid), stained with Semichon's Carmine, and mounted in Canada Balsam. Nematoda were fixed in 70% glycerin ethyl alcohol, cleared, and examined as temporary mounts in glycerin. Parasitic copepods and isopods were placed in 70% ethyl alcohol.

Prevalence (proportion of infected individuals in a population), mean intensity (average number of parasites per infected host), and mean abundance (average number of parasites per host examined, both infected and uninfected hosts) were calculated. Chi-square analysis was used to assess the relationship between prevalence and season as well as between prevalence and host age for the most common macroparasites of Pacific sanddab. Parasite intensities were log-transformed to adjust for skewed distributions and mean parasite intensities were compared among four seasons (summer and fall 1997 and winter and spring 1998) and three age classes. Pooling 3 year old and 4 year old fish produced the 3 year old age class, since few 4 year old sanddabs were collected. The average size of fish in each of the three age classes was 129 mm (range 97–195 mm) for 1 year old sanddabs; 132 mm (range 102–220 mm) for 2 year old sanddabs, and 173 mm (range 109–215 mm) for 3 year old sanddabs. A significance level of $P \leq 0.05$ was used for all statistical tests performed.

Voucher specimens of the following parasites found infecting Pacific sanddab were deposited in the Harold W. Manter Laboratory of Parasitology, University of Nebraska Lincoln: *Anisakis* sp. (HWML 16475), *Corynosoma* sp. (HWML 16474), *Lacistorhynchus dollfusi* (HWML 16472), *Naobranchia occidentalis* (HWML 16476), *Pseudotagia* sp. (HWML 16471), and *Sterrhurus magnatestis* (HWML 16473). Specimens of the host, Pacific sanddab, were deposited at the Natural History Museum of Los Angeles County, Catalog No. 55943-1.

Results and Discussion

Pacific sanddab populations off White Point are infected with 11 species of macroparasites. *Corynosoma* sp. Luhe, 1904 (Order Polymorphida), *Cucullanus* sp. Mueller, 1777 (Ascaridida), *Entobdella hippoglossi* (Mueller, 1776) Blainville, 1818 (Dactylogyrida), *Lacistorhynchus dollfusi* Beveridge and Sakanari, 1987 (Trypanorhyncha), *Lironeca ovalis* Sey 1818 (Isopoda), and *Pseudotagia* sp. Yamaguti, 1963 (Polyopisthocotylida) represent new host records for Pacific sanddab (Table 1). The state of maturity of some of the helminths infecting sanddab suggests that this host functions as a final host for *Cucullanus* sp., *Pseudotagia* sp., and *Sterrhurus magnatestis* as gravid individuals of these species were found. Sanddabs probably serve as second intermediate hosts for pleroceroids of tetraphyllidean cestodes and *L. dollfusi* and obtained them by feeding on their first intermediate host, crustaceans. *Corynosoma* sp. has an indirect life cycle. Im-

Table 1. Prevalence, mean intensity, mean abundance, and location of helminths infecting Pacific sanddab from White Point, Palos Verdes Shelf 1997 to 1998.

Taxon	Prevalence (percent) (# infected)	Mean Intensity ± SE*	Mean Abundance ± SE	Location**
Digenea				
Sterrhurus magnatestis	(5)(7)	1.0 ± 0.0	0.05 ± 0.02	S, I
Monogenea				
*Entobdella hippoglossi****	(1)(1)	—	—	G
Pseudotagia sp.	(10)(14)	1.8 ± 0.46	0.18 ± 0.06	G
Cestoidea				
Lacistorhynchus dollfusi	(78)(107)	10.1 ± 1.3	7.9 ± 1.1	M
Tetraphyllidean plerocercoids	(2)(3)	2.0 ± 0.0	0.04 ± 0.03	I
Nematoda				
Anisakis sp.	(78)(107)	4.7 ± 0.5	3.6 ± 0.4	LV, M, S, PC, I, MU
Cucullanus sp.	(20)(28)	2.9 ± 0.8	0.6 ± 0.2	S, PC, I
Acanthocephala				
Corynosoma sp.	(2)(2)	1.0 ± 0.0	0.01 ± 0.01	M
Copepoda				
Phrixocephalus cincinnatus	(2)(2)	1.0 ± 0.0	0.01 ± 0.01	E
Naobranchia occidentalis	(26)(35)	2.29 ± 0.36	0.58 ± 0.13	G
Isopoda				
Lironeca ovalis	(7)(9)	1.1 ± 0.1	0.07 ± 0.02	G

* SE = standard error of the mean.

** Location in host: E = eye; G = gill, LV = liver, M = mesentery, S = stomach, PC = pyloric ceca, I = intestine, MU = muscle.

*** Only one host was infected with the parasite.

mature stages of this helminth occur in amphipods and fishes. Marine mammals, like the California sea lion, *Zalophus californianus,* function as definitive hosts. Few fish were infected with the parasitic arthropods *L. ovalis* and *Phrixocephalus cincinnatus* (Table 1). Perkins and Gartman (1997) have previously addressed the usefulness of *P. cincinnatus* as a biological indicator of water quality. These authors noted that there appears to be a relationship between the prevalence of *P. cincinnatus* and the distance of its host from outfall sites. However, Perkins and Gartman (1997) found the overall level of infection of sanddabs to be low. This was also the case in the present study as only 2% of Pacific sanddab on the PVS were infected with the eye copepod, *P. cincinnatus.*

Gill copepods (*Naobranchia occidentalis*), juvenile anisakine nematodes (*Anisakis* sp.), and plerocercoids of *L. dollfusi* dominated the infracommunity of Pacific sanddab. The latter two species were often found encysted within the mesentery. Prevalence of these macroparasites varied significantly over the seasons studied. Both *Anisakis* sp. and *L. dollfusi* were more prevalent in winter (83% and 92%, respectively) and spring (89% and 94%, respectively) compared to summer (58% and 52%, respectively) and fall (54% and 71%, respectively). The highest prevalence of *N. occidentalis* was seen in fall (49%) and the lowest in winter (8%). Only mean intensities of *L. dollfusi* were significantly different sea-

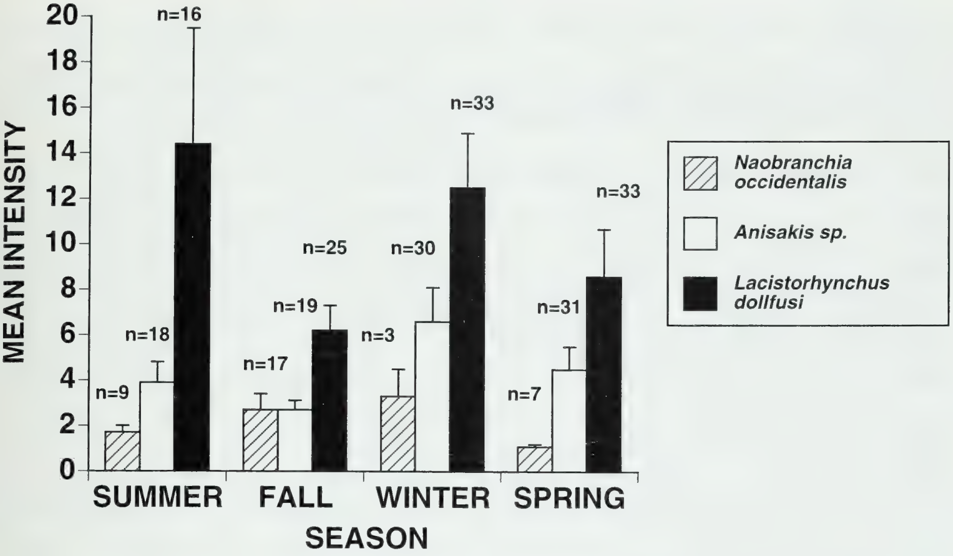

Fig. 1. Seasonal mean intensity of 3 common macroparasites infecting Pacific sanddab from White Point, Palos Verdes Shelf, during four seasons: summer and fall 1997, and winter and spring 1998. N is the number of infected hosts per season. Only the mean intensities of *L. dollfusi* were found to be significantly different seasonally ($F_{3,103}$) = 3.08, P = 0.03.

sonally with the highest mean intensity of these parasites occurring in summer (Fig. 1). Mean intensities of *Anisakis* sp. and *L. dollfusi* were also compared among 3 age classes of sanddab, but no significant differences were seen (for *Anisakis* sp. $F_{2,80}$ = 0.36, P = 0.70 and for *L. dollfusi* $F_{2,90}$ = 0.16, P = 0.85).

Seasonal changes in prevalence of fish parasites is common (Chubb 1982) and can be influenced by several factors including temperature and host diet (Williams and Jones 1994). Although temperature data were not collected at the time sanddabs were obtained for this study, this variable can affect the development of macroparasites like parasitic copepods (Conley and Curtis 1993).

Pacific sanddab, a bothid and demersal fish species, is an opportunistic feeder (it readily consumes crustaceans, polychaete worms, razor clams, and juvenile rockfish) that can tolerate disturbed and polluted habitats like that of the PVS (Cross et al. 1985; Rackowski and Pikitch 1989). Crustaceans, like euphausiids, can be a substantial component of the diet of sanddabs (Hopkins and Hancock 1980) and euphausiids can serve as intermediate hosts for *Anisakis* sp. (Smith and Wootten 1978). Benthic faunal assemblages do vary on the PVS, being influenced by such things as pollution, El Niño, and even strong storms (Thompson et al. 1993). It is possible that seasonal and geographical availability and distribution of crustacean prey could account for differences in the seasonal prevalence of *Anisakis* sp. and *L. dollfusi* in Pacific sanddab.

Although sanddab populations from White Point are infected with 11 different taxa, the average sanddab host had only 2 parasite taxa. Reduced numbers of parasite taxa as well as the total number of parasites per host may reflect changes in intermediate and/or final host population sizes (Overstreet 1997). Further studies are needed on parasite populations of Pacific sanddab from less polluted areas in the SCB to assess their feasibility as a model for tracking pollution exposure in their host.

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Interactive Effects of Diurnal Period and Seasonality on Water Potentials of *Acacia,* and Parasitic and Autoparasitic *Phoradendron*

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Abstract.—Comparative diurnal and seasonal water potentials of *Acacia greggii,* and parasitic and autoparasitic *Phoradendron californicum* were quantitatively investigated in the Las Vegas Valley of southern Nevada. A perennial *P. californicum* plant was autoparasitic on another *P. californicum* plant, which in turn was parasitic on an *A. greggii* host plant. Autoparasitic *P. californicum* plants had significantly lower (more negative) diurnal and seasonal water potentials than parasitic *P. californicum* plants, which had significantly lower water potentials than their *A. greggii* hosts. Water potentials of hosts, parasites, and autoparasites were significantly lower in midday than predawn hours. All plants were significantly more water stressed in the summer than in the spring. Significant interactions were detected between hour of day (diurnal period) and seasonality for water potentials of *A. greggii* hosts, and parasitic and autoparasitic *P. californicum* plants. Plant water potentials were also significantly correlated with diurnal period and seasonality, and even more correlated with diurnal/seasonal combination in southern Nevada.

Phoradendron californicum are perennial, dwarf hemiparasites which once established, rely entirely upon their hosts for their supply of water and various mineral nutrients (Hollinger 1983). *Phoradendron californicum* plants mainly derive limited resources from their *Acacia greggii* hosts by direct xylem connection (Leonard and Hull 1965; Raven 1983; Kaufman 1989). *Acacia greggii* are hosts for *P. californicum,* and these parasites have exploited every conceivable habitat on their host branches.

Water potentials are more negative in *P. californicum* tissues than in *A. greggii* host tissues (Scholander et al. 1965). *Phoradendron californicum*-infested trees had significantly lower (more negative) diurnal and seasonal water potental values than uninfested trees in southern Nevada (Lei 1999).

Phoradendron californicum plants can be epiparasized by other individuals of *P. californicum,* which are in turn growing on *A. greggii* and *Cercidium floridum* host trees (Kuijt 1969; Ehleringer and Schulze 1985; Lei 2000a). However, epiparasitism, also known as autoparasitism, occurs infrequently (Ehleringer and Schulze 1985). Only a limited number of autoparasitic *P. californicum* individuals have been found in northwestern Arizona (Ehleringer and Schulze 1985), southern Nevada, and southeastern California (Lei 2000a and b). The nutrient composition and infection success of this autoparasite have been documented (Ehleringer and Schulze 1985; Lei 2000a and b, respectively). Mineral concentrations in autoparasites were typically 1.1 to 1.3 times higher than in their parasitic and non-parasitic (*C. floridum*) hosts (Ehleringer and Schulze 1985). Age and size of *A. greggii* hosts are significantly positively correlated with the infection success of autoparasites (Lei 2000a). Autoparasites had significantly lower canopy area, flower and fruit production than parasites in southern Nevada (Lei 2000b).

Nevertheless, diurnal and seasonal water potentials of autoparasitic *P. californicum* plants have not been quantitatively investigated in southern Nevada. Two hypotheses were made prior to data collection. First, the ratio of water potentials for autoparasitic *P. californicum* plants to parasitic *P. californicum* plants would be of similar magnitude as compared to the ratio of water potentials for the parasitic *P. californicum* plants to their *A. greggii* hosts. Second, there would be interactions and correlations between the diurnal/seasonality combination and leaf water potentials of hosts, parasites, and autoparasites. These two hypotheses were tested by field measurements with appropriate statistical analyses.

Materials and Methods

Study Site and Field Measurements

Field studies were conducted within the Las Vegas Valley (36°15′N, 115°00′W; elevation 770 m) of southern Nevada in March (spring) and July (summer) 2000. This site, located along the intermittent Tropicana Wash, was chosen based on the presence of limited autoparasitic *P. californicum* individuals. The vegetation zone was dominated by *Atriplex spp.,* with a scattered distribution of *Larrea tridentata, Pluchea sericea, Tamarix ramosissima,* and *Hymenoclea salsola.* The Tropicana Wash can be rapidly filled with running surface water during and shortly after major storm events (Lei 1999).

The four seasons are well defined. Summers display desert conditions, with maximum temperatures usually in the 40°C range. The average annual rainfall is approximately 105 mm (NOAA, Local climatological data, Las Vegas). Rainy days average less than one in June to three per month in the winter months. Occasional summer monsoonal thunderstorms and episodic winter rainfalls are a major contribution to the total annual precipitation, which can vary considerably from year to year (Rowlands et al, 1977). Soil erosion, especially along wash edges, is evidence of the intensity in some of the summer thunderstorm activity. Winter air temperatures are generally mild and pleasant. Winter rainfalls are mild, and may last up to several days (Rowlands et al. 1977). A relative humidity of 20 % or less and extremely high evaporation are common in summer seasons (Lei and Walker 1997a and b).

A total of 16 live autoparasites was found growing on five *A. greggii* hosts. All autoparasites found were alive, although portions of some autoparasitic canopies appeared to be dead with no phenophases and with extremely brittle foliages. From casual observations, autoparasites had little or no direct contact with *A. greggii* hosts. These autoparasites were found with *A. greggii* hosts bearing numerous mature individuals of parasitic *P. californicum.*

Hosts, parasites, and autoparasites were tagged with a brightly colored yarn before water potential measurements to facilitate sampling in the same canopies throughout the day. For each diurnal period, four 10 to 15-cm long terminal shoots were randomly selected from each tagged plant. Diurnal and seasonal water potentials of hosts, parasites, and autoparasites were obtained using a portable pres-

Table 1. Diurnal and seasonal water potentials (mean ± SE, n = 4 per hour per organism) of *A. greggii* hosts, and parasitic and autoparasitic *P. californicum* plants in the Las Vegas Valley of southern Nevada.

		Water potential (MPa)		
Month	Hour of day	Host	Parasite	Autoparasite
March	6	−1.6 ± 0.1	−2.3 ± 0.1	−3.2 ± 0.1
	9	−1.9 ± 0.1	−2.6 ± 0.1	−3.6 ± 0.1
	12	−2.2 ± 0.1	−3.0 ± 0.1	−3.9 ± 0.1
	15	−2.2 ± 0.1	−3.0 ± 0.1	−4.0 ± 0.1
July	6	−2.3 ± 0.1	−3.5 ± 0.1	−4.6 ± 0.1
	9	−2.9 ± 0.1	−4.2 ± 0.1	−5.3 ± 0.1
	12	−3.8 ± 0.1	−5.1 ± 0.2	−6.4 ± 0.2
	15	−3.9 ± 0.1	−5.1 ± 0.2	−6.3 ± 0.2

sure chamber (Plant Moisture Stress Instruments, Corvallis, OR) and nitrogen gas. Once leaves were incised, they were immediately placed in zip-loc plastic bags and housed on ice in the dark until pressurization, which was rapidly conducted at the field site. Diurnal water potentials were measured at predawn (0600 h) and then at 3-hour intervals through 1500 h. Seasonal water potential data were collected twice, once in March and once in July 2000.

Statistical Analyses

Two-way analysis of variance (ANOVA; Analytical Software 1994) was conducted on water potentials of *A. greggii* hosts, parasitic and autoparasitic *P. californicum* plants, with hour of day (diurnal period) and seasonality (March and July) as main variables. One-way ANOVA, followed by Tukey's Multiple Comparison Test (Analytical Software 1994) was used to detect differences in diurnal and seasonal water potentials among host, parasites, and autoparasites, and to compare means when a significant environmental effect was detected, respectively. Linear regression analysis (Analytical Software 1994) was performed to correlate plant water potentials with diurnal period, seasonality, and diurnal/seasonality combination. Mean values are expressed with standard errors, and P-values less than or equal to (≤) 0.05 are reported as statistically significant.

Results

Diurnal and seasonal water potentials of autoparasitic *P. californicum* plants were significantly ($P \leq 0.001$) lower compared to parasitic *P. californicum* plants, which were significantly lower ($P \leq 0.001$) than their *A. greggii* hosts (Table 1). Hosts, parasites, and autoparasites revealed a significantly lower midday than predawn water potential irrespective of seasonality. These plants also exhibited a significantly lower water potential in the summer than in the spring season regardless of diurnal period (Table 1). The mean summer water potential of autoparasites approached −6.5 MPa, with water potentials averaging 1.2 below parasites, which were averaging 1.3 below the hosts (Table 1). However, during the spring season, water potential ratios were lower between autoparasites and parasites (1.0) and between parasites and hosts (0.8) (Table 1).

Significant interactions were detected between diurnal period and seasonality

Table 2. Two-way ANOVA of the effects of diurnal period, seasonality, and their interactions on water potentials of *A. greggii* hosts, and parasitic and autoparasitic *P. californicum* plants. Significance levels: *: P ≤ 0.05; **: P ≤ 0.01; ***: P ≤ 0.001; and ns = Non-Significant.

Environmental variable	df	Host		Parasite		Autoparasite	
		F	P	F	P	F	P
Diurnal period	3	89.28	0.0000***	160.05	0.0000***	260.04	0.0000***
Seasonality	1	507.25	0.0000***	1819.61	0.0000***	2305.72	0.0000***
Diurnal/Seasonality	3	18.67	0.0000***	21.68	0.0000***	19.31	0.0000***

for water potentials of *A. greggii* hosts, and parasitic and autoparasitic *P. californicum* plants (P ≤ 0.001; Table 2). Moreover, plant water potentials were significantly correlated (P ≤ 0.05) with durnal period and seasonality, and even more correlated (P ≤ 0.001) with diurnal/seasonality combination (Table 3).

Discussion

Interactive effects of diurnal period and seasonality on water potentials of *A. greggii* hosts, and parasitic and autoparasitic *P. californicum* plants were examined in the Las Vegas Valley of southern Nevada. Autoparasites consistently and significantly had lower diurnal and seasonal water potentials than their parasitic hosts, which in turn had significantly lower water potentials than their *A. greggii* hosts.

Diurnal water potentials varied significantly in both spring and summer seasons, with a greater variation in mid-summer. Plant water potentials declined significantly from spring to summer. Seasonal reductions in plant water potentials are primarily due to reduced water availability in the soil in southern Nevada (Smith et al. 1995). From casual observations, large portions of parasitic and autoparasitic *P. californicum* canopies turned brown as water stress intensified during the peak of dry summer season. Among the three types of plants, autoparasitic *P. californicum* individuals consistently had the lowest water potential because of greatest water stress. Autoparasites were most water-stressed during midday hours in the summer. The diurnal/seasonality combination may adversely affect potential carbon gain because more and more autoparasitic canopies are turning from green to dark brown, and thus shorten the potential growth season. Low-host water potentials may limit the long-term infection and reproductive success of parasites and autoparasites.

In this study, water potential ratios were similar between autoparasites and parasites and between parasites and hosts in both spring and summer seasons,

Table 3. Correlation coefficient (R^2) for the relationship between diurnal period, seasonality, as well as diurnal period/seasonality combination and water potentials of *A. greggii* hosts, and parasitic and autoparasitic *P. californicum* plants. Significance levels: *: P ≤ 0.05; **: P ≤ 0.01; ***: P ≤ 0.001; and ns = Non-Significant.

Environmental variable	Host	Parasite	Autoparasite
Diurnal period	0.29 **	0.19 *	0.21 *
Seasonality	0.59 ***	0.76 ***	0.72 ***
Diurnal/seasonality	0.88 ***	0.95 ***	0.93 ***

with greater ratios during mid-summer. Parasites obtain limited water and various mineral nutrients from their hosts; autoparasites in turn obtain even more limited resources from their parasitic hosts (Lei 2000a). *Phoradendron californicum* plants are characterized by very low water use efficiencies, and must maintain more negative water potentials than their hosts in order to obtain water in southern California (Jordan et al. 1997). In an autoparasite-parasite system involving *P. californicum* with *A. greggii* as the host, water use efficiency is highest in the host and lowest in the autoparasite in northwestern Arizona (Ehleringer and Schulze 1985). The differences in water use efficiency, including transpiration rates, between host and parasite and between parasite and autoparasite, are of similar magnitude (Ehleringer and Schulze 1985). Since both parasitic and autoparasitic *P. californicum* plants access the same xylem water from their *A. greggii* hosts, autoparasites utilize approximately 10–30% more water per increment growth than their parasitic host (Ehleringer and Schulze 1985). Both parasites and autoparasites must constantly acquire water from, and at the expense of, their *A. greggii* hosts (Lei 2000a).

Only a limited number of autoparasitic *P. californicum* plants were observed under natural field conditions partially because autoparasites, establishing on heavily infested hosts, experienced a significantly greater water stress than parasites. Occasional severe droughts occur in southern Nevada; yet, the timing and duration of each drought vary considerably. Within a single, heavily infested *A. greggii* host, parasites and autoparasites face their own intraspecific interactions, especially density-dependent interference and exploitation competition. Autoparasitism is a condition in which three organisms live together, but autoparasitic *P. californicum* plants derive nourishment at the expense of their parasitic hosts, which in turn derive nourishment from their *A. greggii* hosts. Under extreme cases, *Acacia greggii* hosts can support many adult (well-established) *P. californicum* plants before *P. californicum* plants experience intraspecific competition, *P. californicum*-induced, or drought-induced mortality that takes the parasites, autoparasites, along with their hosts in southern Nevada.

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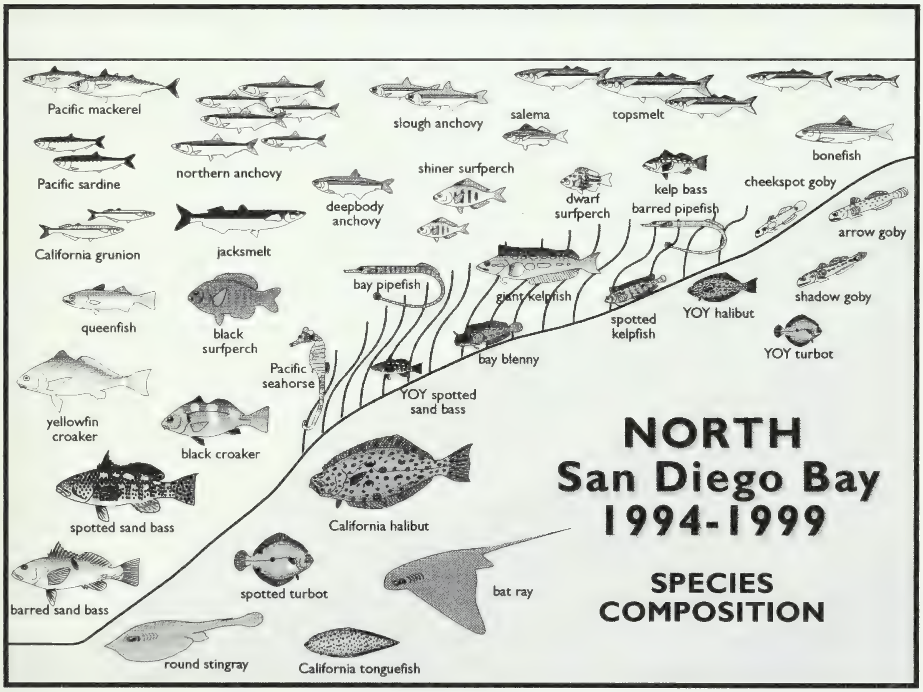
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Structure and Standing Stock of the Fish Assemblages of San Diego Bay, California from 1994 to 1999

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Abstract.—Twenty quarterly samples were taken of the fish assemblages of San Diego Bay from July 1994 to April 1999. Each quarter, four stations were occupied using a variety of sampling methods (large seine, small seines, square enclosure, purse seine, beam trawl, and otter trawl) designed to assess all components of the ichthyofauna. These samples yielded a total of 497,344 fishes belonging to 78 species and weighing 2,775 kg over the five-year period. Northern anchovy was the most abundant fish species comprising 43% of the total catch despite its virtual absence in 1997–98, followed by topsmelt, the slough anchovy and Pacific sardine. Round stingrays dominated in weight constituting almost 25% of the total biomass taken followed by spotted sand bass, and northern anchovy. Both numerical abundance and biomass were highest in the spring and summer months due largely to heavy recruitment of juvenile surfperches, topsmelt and northern anchovies. Large catches of northern anchovies, Pacific sardines, round stingrays, and spotted sand bass also contributed to the pronounced peaks in most July samples. Approximately 70% of all individual fish captured in San Diego Bay during this study were juveniles. The 40 most common species/recruits clustered into eleven, resident and seasonal groups. According to canonical correlation analysis, distance from the mouth of the bay, depth, temperature, and salinity accounted for nearly 88% ($R^2 = 0.875$) of the variance in species abundances.

In general, the fish assemblages of San Diego Bay were found to be diverse, abundant, highly seasonal, and highly productive. The bay serves as a significant nursery area for at least 28 species of fish while presenting a unique combination of harbor, nearshore soft bottom, and bay/estuarine habitats which each contribute unique sets of species to the overall assemblage. One of these sets includes 12 species which are indigenous to the bays and estuaries of southern California. South San Diego Bay represents a crtical habitat for these unique bay/estuarine species whose habitats have disappeared at an alarming rate during the last half century. The extensive shallow water habitat and eelgrass beds also support a very high standing stock of midwater, schooling (forage) fishes, such as northern anchovies, slough anchovies and topsmelt which, in turn, serve as an important forage resource for larger predatory fishes and marine birds. In addition, the general warm and hypersaline waters of south San Diego Bay offer a warm water refuge for a number of southern, "Panamic" province fish species making it unique among all other southern California embayments.

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[*] Corresponding author.

Introduction

Bays and estuaries normally are considered to be important nursery areas for coastal marine fishes (Haedrich and Hall, 1976; Cronin and Mansueti, 1971). The warm spring-summer water temperatures coupled with high productivity enable these environments to support large numbers of juvenile fish. Southern California bays and estuaries are relatively small and scarce when compared to the large, river-dominated estuaries common in other parts of the world. They do, however, function as nursery areas in the classical sense for some species. At least one commercially important species (California halibut, *Paralichthys californicus*) has been shown to rely heavily on southern California bays and estuaries as nursery areas (Allen, 1988). Juveniles of non-commercial fishes can be extremely abundant and usually dominate the fish assemblages of bays and estuaries in the Southern California Bight (Allen, 1982). Many of these abundant, non-commercial species (e.g. gobies, anchovies, and silversides) are important forage fishes for commercial fish species (Horn, 1980) and sea birds. Another characteristic of the fish assemblages from southern California bays and estuaries which is often overlooked is that these habitats support a unique set of species found nowhere else in the bight (Horn, 1980; Allen, 1985).

The principal, resident species found in the smaller bays and estuaries of the Bight include topsmelt (*Atherinops affinis*), California killifish (*Fundulus parvipinnis*), striped mullet (*Mugil cephalus*), longjaw mudsucker (*Gillichthys mirabilis*), arrow goby (*Clevelandia ios*), shadow goby (*Quietula ycauda*), cheekspot goby (*Ilypnus gilberti*), yellowfin goby (*Acanthogobius flavimanus*—introduced), deepbody anchovy (*Anchoa compressa*), slough anchovy (*Anchoa delicatissima*), shiner surfperch (*Cymatogaster aggregata*), black surfperch (*Embiotoca jacksoni*), diamond turbot (*Hypsopsetta guttulata*), and juvenile California halibut (*Paralichthys californicus*), spotted sand bass (*Paralabrax maculatofasciatus*), round stingray (*Urolophus halleri*), and yellowfin croaker (*Umbrina roncador*) (Horn and Allen, 1981).

California killifish and longjaw mudsuckers are most abundant in the shallow tidal channels of the marsh islands. Topsmelt, striped mullet, deepbody anchovy, and slough anchovy inhabitat the water column of both the main channels and along the shoreline, although topsmelt and mullet feed on the bottom. The five species of gobies (family Gobiidae) as a group are the most abundant benthic fishes along the shoreline. The deeper channels are inhabited mainly by residents and seasonal migrants including shiner surfperch, black surfperch, diamond turbot, juvenile California halibut, spotted sand bass, juvenile barred sand bass, yellowfin croaker, and round stingray (Horn and Allen, 1981).

San Diego Bay is the largest naturally occurring marine embayment between San Francisco and Scammon's Lagoon in central Baja California containing approximately 12,000 acres (4,858 ha) of marine habitat (San Diego Unified Port, 1990). As a whole, the bay provides expansive and diverse habitats for fishes including deep channels, marinas, and extensive shallows largely covered with eelgrass. Only the lower portion, South San Diego Bay, appears comparable to other Southern California bays and estuaries in terms of physical and biotic characteristics. The overall goal of this study was to provide the first definitive assessment of the fish populations inhabiting this important coastal habitat.

Since 1968, the fish populations of San Diego Bay have been the subject of numerous monitoring studies with most being concentrated in the to the South San Diego Bay region (Ford 1968, 1985, & 1986, Ford et al. 1971, Lockheed 1979, San Diego Unified Port District 1980, San Diego Gas & Electric Co. 1980, Lockheed 1983). Most of these studies were limited in scope and duration. A comprehensive review of all work and the work in South San Diego Bay, in particular, is presented in San Diego Unified Port District (1990). No comprehensive studies of the fish populations of the entire bay existed prior to the present study.

San Diego Unified Port District (1990) also presented the most complete work on the South San Diego Bay fish populations yet completed. Sampling was conducted on a quarterly basis throughout the south bay in 1988–89. The sampling included multiple gear protocol (otter trawls, gill nets, beam trawls, and two sizes of beach seine) to effectively sample the major subhabitats utilized by fishes. This study concluded that the species composition, relative abundances, and biomass contributions of the south bay fishes have remained very similar since 1968. Topsmelt, slough anchovy, arrow goby, barred pipefish, and California killifish were the most numerically abundant species found in South San Diego Bay while round stingrays, California halibut, and spotted sand bass dominated in terms of biomass.

Hoffman (1986) compared abundance and biomass of fish utilizing eelgrass beds and adjacent non-vegetated areas in three sections of San Diego Bay. Beach seine hauls were made in the north, central, and south portions of the bay on a quarterly basis from July 1980 through April 1981. Topsmelt, shiner surfperch, and three species of gobies (arrow, cheekspot, and shadow) made up 93% of the individuals taken. Topsmelt, shiner surfperch, spotted sand bass, staghorn sculpin, round stingray, and California halibut comprised more than 87% of the fish biomass sampled. Hoffman (1986) concluded that nearly twice as many individual fish and fish species were taken at eelgrass sights than non-vegetated sites when all samples were considered. Furthermore, the total number of individuals and total biomass seemed to remain relatively constant from season to season in these shallow nearshore areas. Hoffman's (1986) results underscore the importance of the eelgrass habitat in San Diego in supporting juvenile and adult fish populations. This study served as a major impetus for the present study, which will eventually provide a statistically reliable comparison of fish numbers and biomass between vegetated (eelgrass) and non-vegetated areas.

The most recent work on the fishes of San Diego Bay was a long-term beach seine study also conducted by Hoffman (1995; and unpubl. data). A single station at the base of the Coronado Bridge has been sampled quarterly since January 1988. This sight corresponds directly with the station 2, vegetated site in the present investigation.

Finally, since 1985, nine, southern or "Panamic", fish species have been recorded from San Diego that add to the overall species list recorded from the bay (Table 1).

The overall objectives of this study were to: 1) identify, quantify and determine the seasonal utilization of the fish populations in San Diego Bay, 2) identify key habitats that support juvenile fish species, and 3) determine geographic and/or habitat areas of San Diego Bay that support significant populations of fish species

Table 1. Exotic, southern species recorded in San Diego Bay in the literature from 1985 to 1991.

Common name	Scientific name	Citation	Collection date
Anchoveta	*Ctengraulis mysticetus*	Duffy (1987)	1986?
Pacific cervalle jack	*Caranx caninus*	Duffy (1987)	1986?
Bonefish	*Albula vulpes*	Duffy (1987)	1986?
White mullet	*Mugil curema*	Lea et al. (1988)	May 1985
Milkfish	*Chanos chanos*	Duffy and Bernard (1985)	1985?
Pacific seahorse	*Hippocampus ingens*	Jones et al. (1988)	?
Cortez grunt	*Haemulon flaviguttatus*	Lea and Rosenblatt (1992)	May 1991
Bigeye trevally	*Caranx sexfasciatus*	Lea and Walker (1995)	Nov 1990
Mexican lookdown	*Selene brevoorti*	Lea and Walker (1995)	Nov 1990

utilized as forage by endangered avian species. To these ends, the following were determined and will be described for the five-year period, July 1994 to April 1999 in San Diego Bay: 1) physical and chemical (PC) factors, 2) species composition and abundance, 3) principal species, 4) species diversity, 5) abundance by bay ecoregion, 6) seasonal abundance, 7) ecological importance of species, 8) nursery area function, 9) fish assemblage structure, 10) abundance patterns in relationship to PC factors, 12) numerical and biomass density, 13) density and standing stock of forage species, and 14) density and standing stock of fisheries species.

Methods and Materials

Station Locations

In order to assess the status of all components of the ichthyofauna of San Diego Bay, we sampled intensively at four stations located in each of four geographic sections (north, north-central, south-central, and south) of bay (Figure 1).

At each station, five subhabitat types were sampled. These subhabitats are designated as follows (from deep to shallow water): 1) channel, 2) nearshore, non-vegetated, 3) nearshore, vegetated, 4) intertidal, non-vegetated, and 5) intertidal vegetated.

Sampling Procedures

The actual sampling locations for each type of gear within each station subhabitat were selected randomly for each sampling period. Sampling was conducted on a quarterly basis from July 1994 to April 1999. Each station was occupied on a separate day in order to sample each section thoroughly with a multiple gear approach. The use of multiple gears was necessary to adequately sample all of the habitat types available to the fishes of San Diego Bay. Collections were carried out using the R/V Yellowfin (California State University) as our base of operations with much of the work was conducted out of two, 5 m Boston Whalers. At each station, the following gear types were employed:

1) A 15.2 × 1.8 m **large seine** fitted with a 1.8 × 1.8 × 1.8 m bag (1.2 cm mesh in wings and 0.6 cm mesh in bag) was utilized to sample juvenile fishes in the nearshore portion of the station at a depth of 0–2 m. This net was set parallel to shore and hauled to shore by 15 m lines. This seine is an accurate sampler of nearshore schooling fishes and gives reliable density estimates. Two replicate hauls were made at each station, each of which covered about 220 m^2.

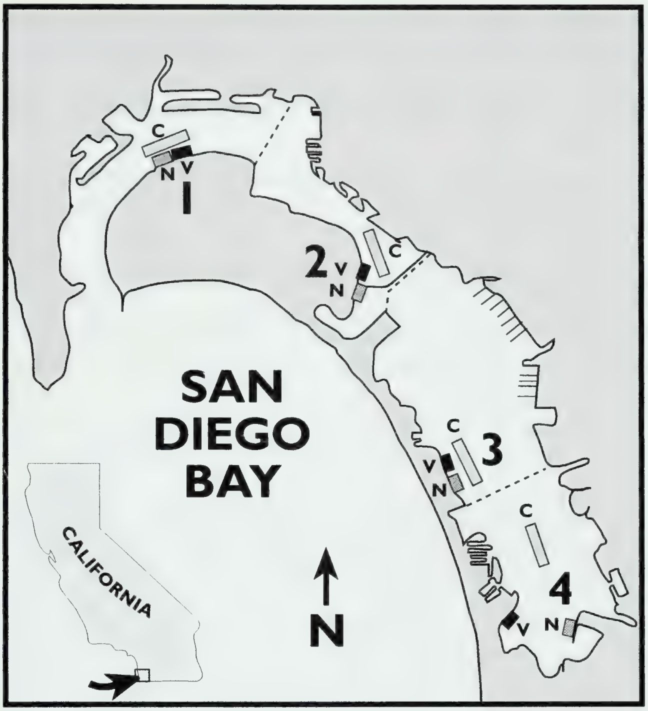

Fig. 1. Map of San Diego Bay illustrating the locations of the 4 sampling stations. (N = Non-vegetated site; V = Vegetated site; C = Channel site).

2) A 4.6 m × 1.2 m **small seine** (3 mm mesh) was employed to collect juvenile and adult fishes occupying the shallow, inshore areas (0–0.5 m depth). The small seine was hauled 10 m along shore and pivoted shoreward yielding a consistent areal coverage of about 62 m^2.

3) A **square enclosure** (1m × 1m × 1m) constructed of 2.5 cm PVC pipe and canvas was used to sample small, burrow inhabiting fish species such as gobies in the shallow waters of the bay. The enclosure was set randomly within each subhabitat in a depth range of 0.25 to 0.75 m and firmly settled into the substrate. One liter of 3:1 acetone-rotenone solution was then added to the enclosed water column and the substrate searched thoroughly for 10 min. with a 1 mm mesh, long-handled dipnet. This device samples an area of 1.0 m^2.

4) A 1.6 m **beam trawl** with 4 mm mesh in the wings and 2 mm knotless mesh in the codend. Standardized ten minute tows were be made behind the 5m Boston Whalers covering about 290 m^2.

5) A 66 × 6 m **purse seine** (1.2 cm mesh in wings and 0.6 cm mesh in bag) was utilized to sample juvenile and adult fishes in the water column of nearshore portion and channel of the station. Purse seine hauls were conducted using a specially out-fitted 5 m Boston Whaler and each sampled about 296 m^2.

6) An 8 m semi-balloon **otter trawl** (2 cm mesh in wings and 0.8 cm mesh in codend) towed behind the R/V Yellowfin was used to sample demersal juvenile and adult fishes from the deepest channel portions of each sampling area covering an average of 2417 m^2.

Large seines, small seines, and square enclosures (all N = 3 each) were used to sample both types of intertidal subhabitat. Both the nearshore subhabitats (non-vegetated and vegetated) were sampled using beam trawls (N = 3 each) and purse seines (N = 3 each). The channel was sampled using otter trawls (N = 3) and purse seines (N = 3).

All fishes or subsamples of large catches were identified, counted and weighed aboard ship or in the laboratory after freezing, to the nearest 0.1g on a Mettler PE2000 digital scale.

Water temperature (°C), salinity (ppt), dissolved oxygen (mgO^2/l), and pH were measured at each station at the shoreline, nearshore surface and bottom, and channel surface and bottom using a Hydrolab Digital 4041 field analyzer. Maximum depth of each station was recorded using Lowrance depth sounders mounted on each Boston Whaler. PC measurements were taken once at each of the four stations during each of the 4 sampling periods. Unfortunately, technical difficulties with the D.O. and pH electrodes in October 1996 prevented the measurements of these parameters during that sampling period.

Data summarization and graphing were accomplished using *Microsoft Excel* and *Statistica* software on an IBM compatible Pentium PC. Data analysis including ANOVA, canonical and regular correlations among PC factors and numbers and biomass were carried out using *Statistica.* As is the usual case with ecological data on fishes, raw catch data were generally non-normal with unequal variances. For this reason, all catch data for number of individuals of all species were log-transformed ($\log_{10}(x + 1)$) before statistical comparisons were made. This transformation generally solved problems of normality and unequal variances in this data set.

The Shannon-Weiner Diversity index (H′):

$$H' = -\sum p_i(\ln p_i) \quad \text{where} \quad p_i = \text{proportion of species i}$$

was calculated for total catches by station and total catch by sampling month. This index incorporates both components of species diversity, species richness and evenness.

In order to determine the relative importance of each species to the energy flow within the fish component of the bay ecosystem, an Index of Community Importance (I.C.I.) was calculated using the total catch for each species over the four years of the study. This index incorporates the three significant ecological variables (% Number, % Weight, and % Frequency of Occurrence by station over month) for each species as follows:

$$\text{I.C.I.} = (\%N + \%Wt) \times \%F.$$

The structure of the fish assemblages was examined using cluster analysis (*Statistica*). Clustering was based on the log-transformed ($\log_{10}(x + 1)$), co-occurrences of the 35 most abundant species in samples summed over gear-type from each station over sampling month and utilized complete linkage and the correlation coefficient, *r,* as the index for distance.

For the current study, the *Best Estimate of Density* within each ecoregion was determined in the following manner: 1) Sample densities estimated by gear type for each species were averaged over all samples within the three depth strata (Intertidal, Nearshore, and Channel). 2) The *maximum* density for each species

Table 2. Estimates of areal coverage of depth strata within the four Ecoregions of San Diego Bay. Proportions and areas were used to weight density estimates and to estimate standing stocks of fishes.

	Intertidal	Nearshore	Channel	Total	% of bay
% AREA Ecoregion					
North	6	33	60		
North-central	5	38	57		
South-central	3	61	36		
South	4	84	13		
Hectares/Habitat Ecoregion					
North	61	327	593	982	20
North-central	41	307	460	808	17
South-central	51	1227	726	2005	41
South	41	890	133	1064	22
# Hectares	194	2751	1913	4858	
% Bay Area	4	57	39		

by gear type within the each depth stratum was determined to be the *Best Estimate of Density* for that species within that depth stratum. 3) The proportional areal coverage of the three depth strata within the ecoregion was determined using a grid on a scaled chart of San Diego Bay (Table 2). These areal proportions were then used to weight the *Best Estimates of Density* within the depth strata by species. A weighted average was then taken among these best estimates over the three depth strata for each species. 4) The sum of the weighted densities of all species then represented the *Best Estimate of Density* (numerical and biomass) for each depth stratum and the Ecoregion (station). 5) Standing stock estimates were then made by simply multiplying the best estimates by the total area of the individual ecoregions and San Diego Bay, as a whole.

Results

Physical and Chemical (PC) Factors

Over the five years of the study, temperature varied from a high of 27.3 °C at Station 4 in July 1997 to a low of 14.9 °C at Station 1 in January 1995 and 1997 (Figure 2). Predictably, the highest mean temperatures were also encountered in the summer of all five years (July 1994, 1995, 1996, 1997 and 1998) and the lowest in the winter (January 1995, 1996, 1997, 1998 and 1999). In January 1998, the mean temperature for the entire bay, while being low, was almost 1.5 degrees higher than the four other January sampling periods. Thermal stratification was evident during all sampling periods with temperatures becoming warmer (2–5 °C) north to south (Station 4 being the warmest) in the bay except in October 1994 when Station 1 had the highest mean temperature (Figure 2).

Surface salinity was relatively stable over the first two years of the study period varying about 6 ppt (39.8 to 33.4 ppt) over the entire year despite heavy rainfall in January of 1995 which had little impact on surface salinity. After July 1996 salinities increased to a peak in October 1996 followed by a dramatic drop-off in January 1997. During the fourth year (1997–98) salinities rose into the summer months then decreased to an overall low of less than 33 ppt in April 1998. Salinities were typically higher than 34 ppt, the average value for sea water. Mean salinities peaked in October of each year (1994, 1995, 1996 and 1997) when 35–

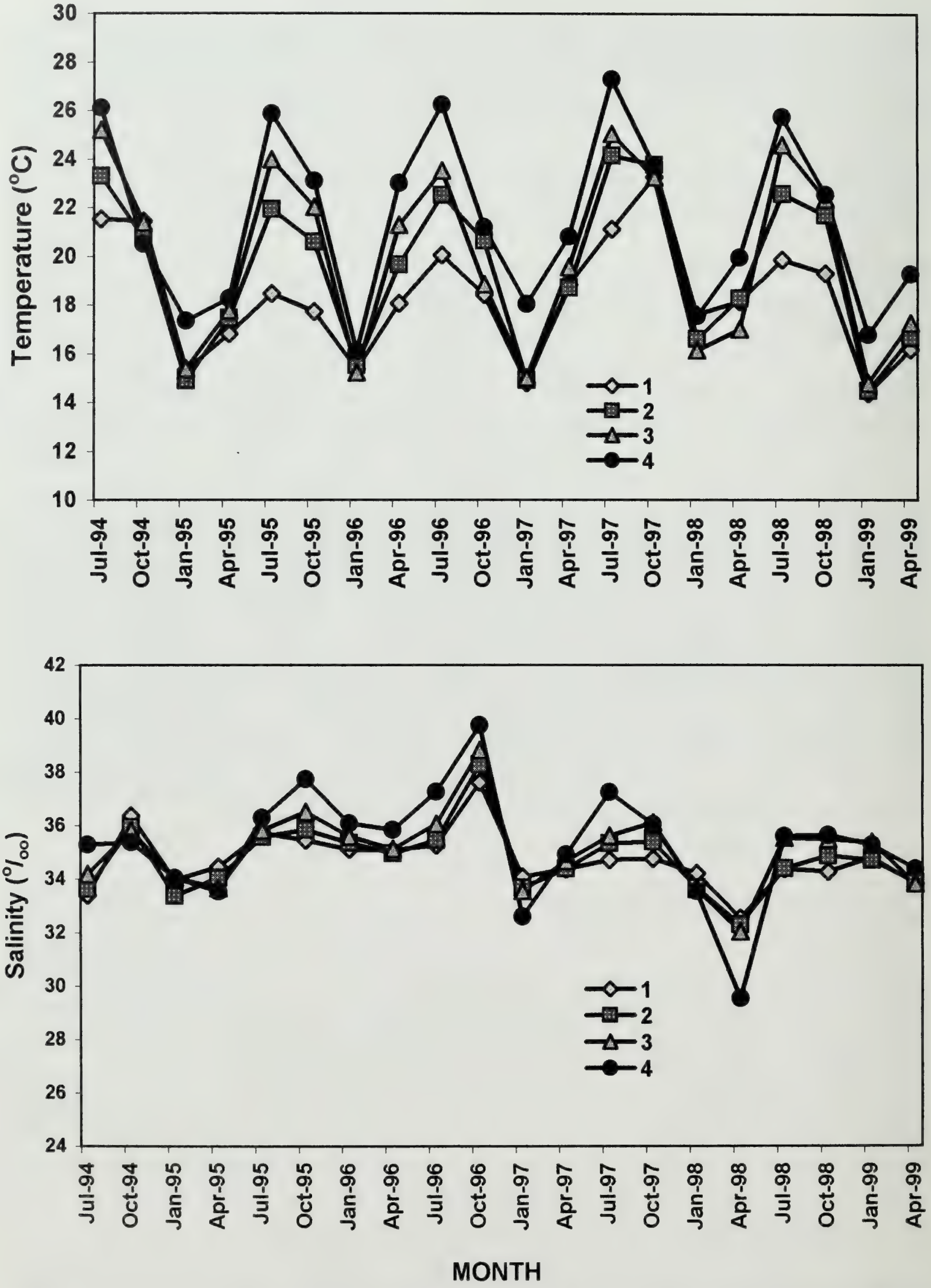

Fig. 2. Summary of Mean Surface Temperature (°C) and Salinity (‰) measurements by Station over the Sampling Months, July 1994 to April 1999.

37 ppt prevailed at all stations, but where particularly hypersaline in October 1996 at station 4 (39.8 ppt) (Figure 2). Salinities were generally lower than 34 ppt in January and April 1998. Overall, mean monthly salinities ranged from 31.6 ppt in April 1998 to 38.6 ppt in October 1996.

Mean surface pH readings were generally varying only from 7.5 in January 1995 to 8.2 in July 1994 while mean surface dissolved oxygen exhibited a range of 7.2 to 9.2 mgO_2/l in July 1995 and April, 1995, respectively. Unfortunately, problems with the calibration and the operation of the Hydrolab remote sensing unit have resulted in numerous unreliable readings for pH and dissolved oxygen. Therefore, it became necessary to exclude pH and D.O. from most analyses.

The eastern Pacific was subjected to a fairly intense El Niño-Southern Oscillation (ENSO) event in 1997–98. This event was clearly reflected in the temperature readings recorded during our sampling in San Diego Bay. Surface water temperature was significantly higher in July 1997 (two-way ANOVA, $F = 8.34$; $df = 3, 4$; $p < 0.01$) than in the four other July samples (1994, 1995, 1996, 1998). In addition, surface water temperature was significantly higher in January 1998 (two-way ANOVA, $F = 5.08$; $df = 3, 4$; $p < 0.05$) than in the other four January samples (1995, 1996, 1997, and 1999).

Surface water temperatures were also elevated at the beginning of the study in July 1994 which may have represented a lag effect of the 1992–93 El Nino event.

Abundance and Biomass

A total of 497,344 fishes belonging to 78 species and weighing 2,775 kg were captured in the 20 sampling dates from July 1994 to April 1998 in San Diego Bay (Table 3 and 4). Northern anchovy remained as the most abundant fish species comprising 43% of the total catch despite its virtual absence in 1997–98, followed by topsmelt at 23%, the slough anchovy at 19%, Pacific sardine at 3% and shiner surfperch at about 2% of the total catch (Table 3). Round stingrays dominated in weight constituting almost 25% of the total biomass taken followed by spotted sand bass at about 14%, northern anchovy at 9%, bat ray, 9%, topsmelt, 9%, and slough anchovy, 7% (Table 4).

The greatest number of individuals was taken at Station 1 (198,141) followed closely by Station 2 (188,147), then Station 3 (57,892), and Station 4 (53,164) (Figure 3). The high count at Station 1 and 2 compared to the other stations was primarily due to the large numbers of juvenile northern anchovy, Pacific sardine, and topsmelt taken at these stations in most years. This northern portion of the bay may represent a preferred nursery area for northern anchovy, Pacific sardine, and topsmelt within San Diego Bay.

The distributions of four of the numerically dominant, schooling species, northern anchovy, topsmelt, slough anchovy, and Pacific sardine showed an interesting pattern. The station abundances of the northern anchovy, topsmelt, and sardine appear to have a positive relationship with these three species dominating in north San Diego Bay. This pattern of abundance was the opposite of that found for the slough anchovy which was prominent in the southern portion of the bay (Figure 4).

The catch in terms of biomass also showed an interesting pattern across stations for all species (Figure 5). Large catches of round stingray and spotted sand bass were taken across all stations. Large catches of northern anchovies at Stations 1

Table 3. Total abundance of fish species taken from San Diego Bay over the five years of the study, July 1994 to April 1999 by station.

		STATIONS, 1994-1999					
SCIENTIFIC NAME	**COMMON NAME**	**1**	**2**	**3**	**4**	**TOTAL**	**%**
Engraulis mordax	northern anchovy	121,888	88,925	3,556	1,249	215,618	43.35
Atherinops affinis	topsmelt	44,055	51,041	12,791	7,693	115,580	23.24
Anchoa delicatissima	slough anchovy	4,315	25,526	31,874	35,106	96,821	19.47
Sardinops sagax	Pacific sardine	12,964	1,417	398	74	14,853	2.99
Cymatogaster aggregata	shiner surfperch	3,191	3,821	3,194	1,051	11,257	2.26
Atherinopsis californiensis	jacksmelt	399	7,290	664	395	8,748	1.76
Leuresthes tenuis	California grunion	4,225	767	600		5,592	1.12
Heterostichus rostratus	giant kelpfish	1,687	1,989	881	131	4,688	0.94
Urolophus halleri	round stingray	715	1,060	720	1,371	3,866	0.78
Syngnathus leptorhynchus	bay pipefish	701	1,394	1,040	292	3,427	0.69
Syngnathus auliscus	barred pipefish	390	777	598	917	2,682	0.54
Clevelandia ios	arrow goby	51	484	82	1,677	2,294	0.46
Paralabrax nebulifer	barred sand bass	311	954	342	240	1,847	0.37
Paralabrax maculatofasciatus	spotted sand bass	226	570	334	347	1,477	0.30
Ilypnus gilberti	cheekspot goby	580	582	70	190	1,422	0.29
Paralichthys californicus	California halibut	316	200	167	250	933	0.19
Quietula ycauda	shadow goby	40	193	84	325	642	0.13
Fundulus parvipinnis	California killifish		29	10	598	637	0.13
Mugil cephalus	striped mullet	8	1	1	510	520	0.10
Hyporhamphus rosae	California halfbeak	18	15	203	174	410	0.08
Anchoa compressa	deepbody anchovy	1	212	23	130	366	0.07
Paralabrax clathratus	kelp bass	268	24	4	2	298	0.06
Embiotoca jacksoni	black surfperch	272	8			280	0.06
Hypsoblennius gentilis	bay blenny	128	129	9	1	267	0.05
Hypsopsetta guttulata	diamond turbot	69	71	43	74	257	0.05
Micrometrus minimus	dwarf surfperch	244	3	2		249	0.05
Seriphus politus	queenfish	216	12			228	0.05
Xenistius californiensis	salema	76	116	24	2	218	0.04
Pleuronichthys ritteri	spotted turbot	120	84	5	8	217	0.04
Cheilotrema saturnum	black croaker	55	39	31	53	178	0.04
Albula vulpes	bonefish	10	115	4	46	175	0.04
Scomber japonicus	Pacific mackerel	11	97	20		128	0.03
Umbrina roncador	yellowfin croaker	42	4	37	27	110	0.02
Gibbonsia elegans	spotted kelpfish	56	35	3	4	98	0.02
Symphurus atricauda	California tonguefish	87	11			98	0.02
Porichthys myriaster	specklefin midshipmai	27	5	10	37	79	0.02
Xystreurys liolepis	fantail sole	62	9		1	72	0.01
Synodus lucioceps	California lizardfish	56	4	2	7	69	0.01
Myliobatis californica	bat ray	27		2	28	57	0.01
Sphyraena argentea	California barracuda	14	43			57	0.01
Scorpaena guttata	California scorpionfish	37	8	1	1	47	0.01
Post-larval anchovy	Post-larval anchovy				45	45	0.01
Strongylura exilis	California needlefish	3	23	9	7	42	0.01
Syngnathus californiensis	kelp pipefish	18	8	14	2	42	0.01
Leptocottus armatus	staghorn sculpin	9	12	11	4	36	0.01
Acanthogobius flavimanus	yellowfin goby		2	7	25	34	0.01
Cynoscion parvipinnis	shortfin corvina	6	8	2	14	30	0.01
Syngnathus exilis	barcheek pipefish	2	7	8	8	25	0.01
Halichoeres semicinctus	rock wrasse	24				24	0.00
Oxyjulis californica	senorita	24				24	0.00
Gillichthys mirabilis	longjaw mudsucker				19	19	0.00
Trachurus symmetricus	jack mackerel	18				18	0.00
Cosmocampus arctus	snubnose pipefish	10	3		1	14	0.00
Genyonemus lineatus	white croaker	13				13	0.00
Hippocampus ingens	Pacific seahorse		7	4	2	13	0.00
Mustelus californicus	gray smoothhound	1	1	1	9	12	0.00
Post-larval goby	Post-larval goby	9				9	0.00
Anisotremus davidsoni	sargo	6		1		7	0.00
Atractoscion nobilis	white seabass	3	1		3	7	0.00
Rhinobatis productus	shovelnose guitarfish	4		2	1	7	0.00
Girella nigricans	opaleye	6				6	0.00
Mustelus henlei	brown smoothhound	5		1		6	0.00
Paraclinus integripinnis	reef finspot	1	3	2		6	0.00
Pleuronichthys coenosus	CO turbot	6				6	0.00
Roncador stearnsii	spotfin croaker	1			5	6	0.00
Gymnura marmorata	California butterfly ray	2			2	4	0.00
Pleuronichthys verticalis	hornyhead turbot		4			4	0.00
Citharichthys stigmaeus	speckled sanddab	3				3	0.00
Dorosoma petenense	threadfin shad				3	3	0.00
Menticirrhus undulatus	California corbina		2		1	3	0.00
Porichthys notatus	plainfin midshipman	1			2	3	0.00
Phanerodon furcatus	white surfperch	2				2	0.00
Zapteryx exasperata	banded guitarfish	2				2	0.00
Gibbonsia metzi	striped kelpfish		1			1	0.00
Heterodontus francisi	California hornshark		1			1	0.00
Medialuna californica	halfmoon	1				1	0.00
Pseudupeneus grandisquamous	red goatfish	1				1	0.00
Pleuronectess vetulus	English sole	1				1	0.00
Rimicola muscarum	kelp clingfish	1				1	0.00
Tridentiger trigonocephalus	chameleon goby			1		1	0.00
TOTAL		**198,141**	**188,147**	**57,892**	**53,164**	**497,344**	
					Number of Species =	**78**	

Table 4. Total biomass (g) of fish species taken from San Diego Bay over the five years of the study, July 1994 to April 1999 by station.

		STATIONS, 1994-1999					
SCIENTIFIC NAME	**COMMON NAME**	**1**	**2**	**3**	**4**	**TOTAL (g)**	**%**
Urolophus halleri	round stingray	175,747	167,033	123,010	221,280	687,070	24.76
Paralabrax maculatofasciatus	spotted sand bass	65,634	152,308	87,005	77,259	382,206	13.77
Engraulis mordax	northern anchovy	138,927	115,387	2,486	1,498	258,297	9.31
Myliobatis californica	bat ray	175,731		17,500	61,336	254,568	9.17
Atherinops affinis	topsmelt	104,236	78,188	29,324	39,800	251,547	9.06
Anchoa delicatissima	slough anchovy	10,395	61,171	65,690	45,201	182,456	6.57
Paralabrax nebulifer	barred sand bass	27,180	35,350	13,494	46,907	122,931	4.43
Paralichthys californicus	California halibut	38,017	22,443	21,142	30,770	112,373	4.05
Cymatogaster aggregata	shiner surfperch	26,621	28,134	17,525	3,653	75,933	2.74
Sardinops sagax	Pacific sardine	46,650	5,547	7,560	4,711	64,467	2.32
Atherinopsis californiensis	jacksmelt	24,109	4,210	2,231	13,875	44,424	1.60
Heterostichus rostratus	giant kelpfish	14,273	13,589	8,407	1,034	37,303	1.34
Hypsopsetta guttulata	diamond turbot	13,600	12,198	4,681	6,228	36,707	1.32
Leuresthes tenuis	California grunion	15,245	10,801	10,007		36,053	1.30
Cheilotrema saturnum	black croaker	5,533	4,520	4,202	8,500	22,756	0.82
Rhinobatis productus	shovelnose guitarfish	10,150		6,595	3,757	20,502	0.74
Scomber japonicus	Pacific mackerel	4,128	11,405	3,647		19,180	0.69
Umbrina roncador	yellowfin croaker	5,684	499	5,793	4,492	16,469	0.59
Pleuronichthys ritteri	spotted turbot	7,829	7,843	154	121	15,948	0.57
Embiotoca jacksoni	black surfperch	13,858	344			14,202	0.51
Cynoscion parvipinnis	shortfin corvina	4,679	4,981	1,476	801	11,937	0.43
Gymnura marmorata	California butterfly ray	7,727			2,714	10,441	0.38
Xystreurys liolepis	fantail sole	4,674	4,175		188	9,036	0.33
Scorpaena guttata	California scorpionfish	6,400	1,161	151	182	7,893	0.28
Seriphus politus	queenfish	6,222	169			6,392	0.23
Mustelus californicus	gray smoothhound	336	968	950	3,793	6,047	0.22
Mustelus henlei	brown smoothhound	4,536		813		5,349	0.19
Porichthys myriaster	specklefin midshipman	2,040	384	1,394	926	4,744	0.17
Trachurus symmetricus	jack mackerel	4,095				4,095	0.15
Strongylura exilis	California needlefish	483	1,771	363	1,137	3,753	0.14
Micrometrus minimus	dwarf surfperch	2,971	38	28		3,037	0.11
Paralabrax clathratus	kelp bass	2,309	496	29	83	2,917	0.11
Xenistius californiensis	salema	44	2,508	260	27	2,840	0.10
Sphyraena argentea	California barracuda	2,009	821			2,830	0.10
Menticirrhus undulatus	California corbina		2,600		150	2,750	0.10
Anchoa compressa	deepbody anchovy	2	592	454	1,479	2,527	0.09
Heterodontus francisi	California hornshark		2,420			2,420	0.09
Symphurus atricauda	California tonguefish	1,976	379			2,354	0.08
Hypsoblennius gentilis	bay blenny	911	1,210	205	3	2,329	0.08
Syngnathus leptorhynchus	bay pipefish	512	650	1,042	101	2,304	0.08
Mugil cephalus	striped mullet	2	0	0	2,270	2,272	0.08
Albula vulpes	bonefish	133	744	42	880	1,799	0.06
Girella nigricans	opaleye	1,796				1,796	0.06
Atractoscion nobilis	white seabass	909	250		568	1,727	0.06
Synodus lucioceps	California lizardfish	1,473	54	45	73	1,645	0.06
Syngnathus auliscus	barred pipefish	313	406	378	519	1,615	0.06
Fundulus parvipinnis	California killifish		111	25	1,318	1,454	0.05
Roncador stearnsii	spotfin croaker	102			1,163	1,265	0.05
Zapteryx exasperata	banded guitarfish	1,067				1,067	0.04
Hyporhamphus rosae	California halfbeak	51	29	676	303	1,059	0.04
Pleuronichthys coenosus	CO turbot	867				867	0.03
Acanthogobius flavimanus	yellowfin goby		22	388	420	830	0.03
Halichoeres semicinctus	rock wrasse	743				743	0.03
Oxyjulis californica	senorita	667				667	0.02
Genyonemus lineatus	white croaker	610				610	0.02
Phanerodon furcatus	white surfperch	605				605	0.02
Anisotremus davidsoni	sargo	18		579		597	0.02
Pleuronichthys verticalis	hornyhead turbot		597			597	0.02
Hippocampus ingens	Pacific seahorse		267	129	91	487	0.02
Leptocottus armatus	staghorn sculpin	119	119	123	60	420	0.02
Gibbonsia elegans	spotted kelpfish	165	150	28	9	352	0.01
Quietula ycauda	shadow goby	18	30	117	103	268	0.01
Ilypnus gilberti	cheekspot goby	115	37	7	71	231	0.01
Clevelandia ios	arrow goby	8	26	6	187	227	0.01
Dorosoma petenense	threadfin shad				224	224	0.01
Syngnathus californiensis	kelp pipefish	86	38	15	3	142	0.01
Pseudupeneus grandisquamous	red goatfish	100				100	0.00
Porichthys notatus	plainfin midshipman	9			61	69	0.00
Gillichthys mirabilis	longjaw mudsucker				51	51	0.00
Citharichthys stigmaeus	speckled sanddab	37				37	0.00
Cosmocampus arctus	snubnose pipefish	2	29		0	31	0.00
Post-larval goby	Post-larval goby	30				30	0.00
Syngnathus exilis	barcheek pipefish	5	7	8	7	27	0.00
Pleuronectes vetulus	English sole	5				5	0.00
Paraclinus integripinnis	reef finspot	1	1	3		5	0.00
Tridentiger trigonocephalus	chameleon goby			4		4	0.00
Post-larval anchovy	Post-larval anchovy				1	1	0.00
Gibbonsia metzi	striped kelpfish		0			0	0.00
Medialuna californica	halfmoon	0				0	0.00
Rimicola muscarum	kelp clingfish	0				0	0.00
TOTAL		**985,530**	**759,210**	**440,185**	**590,386**	**2,775,311**	

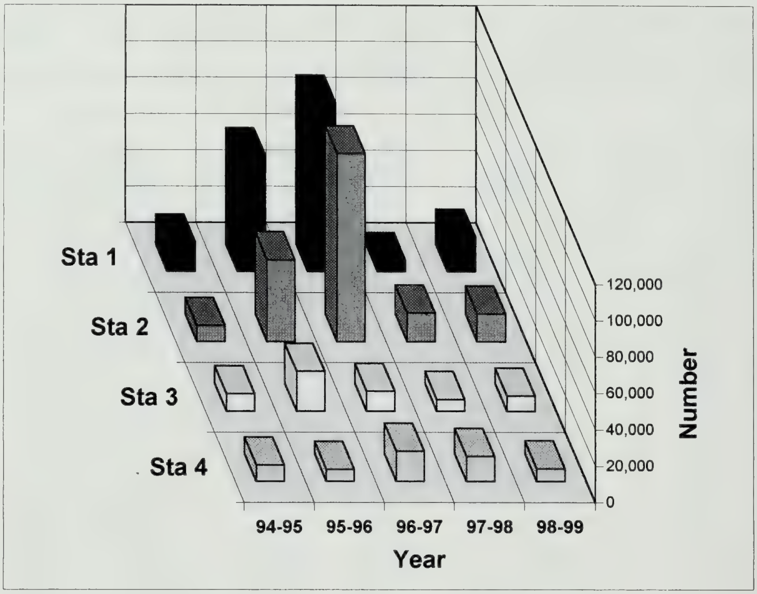

Fig. 3. Abundance of San Diego Bay Fishes by Station, 1994–1999.

and 2, in addition to those of stingrays and spotted sand bass yielded much higher biomass catches in the northern part of the bay.

Abundance by Bay Ecoregion

North (Station 1).—A total of 198,141 fishes belonging to 68 species and weighing 985.5 kg were captured in the North Ecoregion over the 20 sampling

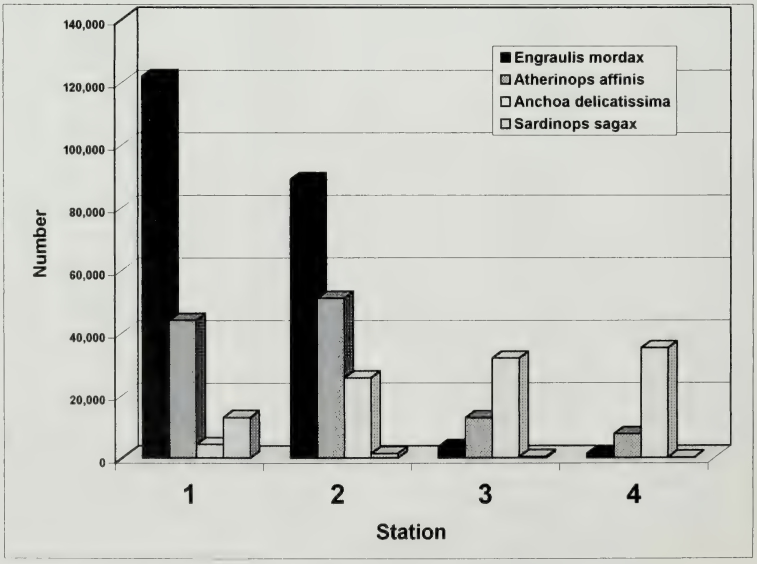

Fig. 4. Abundance of the four numerically dominate species by station in San Diego Bay, July 1994 to April 1999.

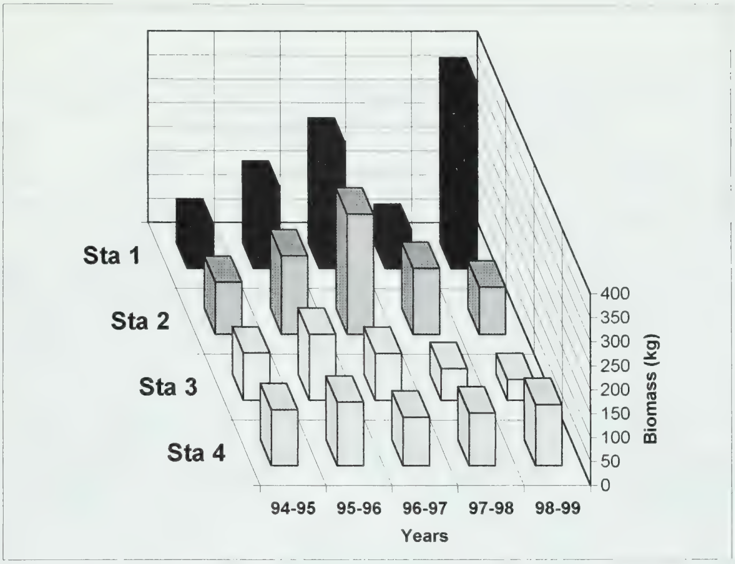

Fig. 5. Biomass (kg) of San Diego Bay Fishes by Station, 1994–1999.

dates from July 1994 to April 1999 (Table 3 and 4). Northern anchovy was the most abundant fish species comprising 62% of the total catch, followed by topsmelt at 22%, Pacific sardine at 5%, slough anchovy, 2%, California grunion (*Leuresthes tenuis*), 2% and shiner surfperch at about 2% of the total catch. Round stingrays led in total biomass at 18% followed closely by bat rays also at 18%, northern anchovy at 14%, topsmelt, 11%, spotted sand bass, 7%, and California halibut, 4%.

North-Central (Station 2).—A total of 188,147 fishes belonging to 55 species and weighing 759.2 kg were captured in the North-Central Ecoregion over the 20 sampling dates from July 1994 to April 1999 (Table 3 and 4). Northern anchovy remained the most abundant fish species comprising nearly 47% of the total catch, followed by topsmelt at 27%, slough anchovy at 14%, jacksmelt at 4%, shiner surfperch at about 2%, and giant kelpfish at approximately 1% of the total catch. Round stingrays constituted the largest portion of total biomass at 22%, followed closely by spotted sand bass, 20%, northern anchovy, 15%, topsmelt, 10%, and slough anchovy at almost 8% (Figure 6).

South-Central (Station 3).—A total of 57,892 fishes belonging to 49 species and weighing 440.2 kg were captured in the South-Central Ecoregion over the 20 sampling dates from July 1994 to April 1999 (Table 3 and 4). Slough anchovy was the most abundant fish species comprising 55% of the total catch, followed by topsmelt at 22%, northern anchovy at 6%, shiner surfperch at about 6%, and bay pipefish at approximately 2% of the total catch. Round stingrays ranked first in total biomass at 28% followed closely by spotted sand bass at 20%, slough anchovy, 15%, topsmelt, 7%, and California halibut, 5%.

South (Station 4).—A total of 53,164 fishes belonging to 51 species and weighing 590.4 kg were captured in the South Ecoregion over the 20 sampling dates from July 1994 to April 1999 (Table 3 and 4). As with station 3, slough anchovy

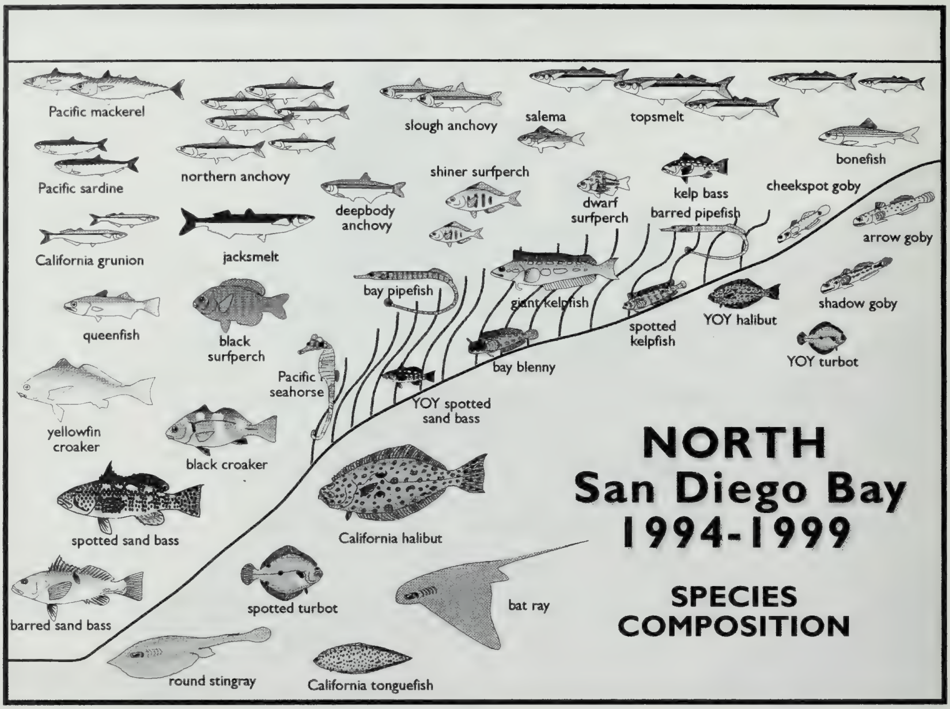
Pacific mackerel
Pacific sardine
California grunion
queenfish
yellowfin croaker
spotted sand bass
barred sand bass
northern anchovy
jacksmelt
black surfperch
black croaker
slough anchovy
deepbody anchovy
bay pipefish
Pacific seahorse
YOY spotted sand bass
California halibut
spotted turbot
round stingray
California tonguefish
salema
shiner surfperch
dwarf surfperch
giant kelpfish
bay blenny
topsmelt
kelp bass
barred pipefish
spotted kelpfish
YOY halibut
bonefish
cheekspot goby
arrow goby
shadow goby
YOY turbot
bat ray
NORTH
San Diego Bay
1994-1999
SPECIES
COMPOSITION

Fig. 6. Diagrammatic representation of the common and distinctive species of fish which occurred in the northern portion (North and North Central Ecoregions) of San Diego Bay during the study period of July 1994 to April 1999.

was, again, the most abundant fish species comprising over 66% of the total catch, followed by topsmelt at 14%, arrow goby at 3%, round stingray at also at 3%, and shiner surfperch at 2% of the total catch. Once again, round stingrays led in total biomass at nearly 37% of the total biomass followed by spotted sand bass at 13%, bat ray at 10%, and barred sand bass at 8% (Figure 7).

South San Diego Bay provides critical habitat for at least 12 fish species (Table 5) which are indigenous to bay and estuarine environments in the Southern California Bight (Allen, 1985).

Seasonal Abundance

Marked changes in the number individuals and total biomass occurred seasonally over the course of the study. When all four stations are considered together, numerical abundance was generally highest in the spring (April 1995, 1996, 1997, 1998, and 1999) and summer (July 1995, 1996, and 1998) months (Figure 8). Heavy recruitment of juvenile surfperches and topsmelt in April of 1995 and 1996 was largely responsible for those abundance peaks (Table 6). Large numbers of topsmelt, slough anchovy, shiner surfperch and California grunion were responsible for relatively high catches in April 1997, while the April 1998 catches were dominated by slough anchovies. Very large catches of juvenile northern anchovy and Pacific sardine caused the pronounced peaks in July 1995 and 1996. Interestingly, July 1997 catches were low due to the virtual absence of northern anchovies. The catch in July 1998 was dominated by slough anchovy, northern

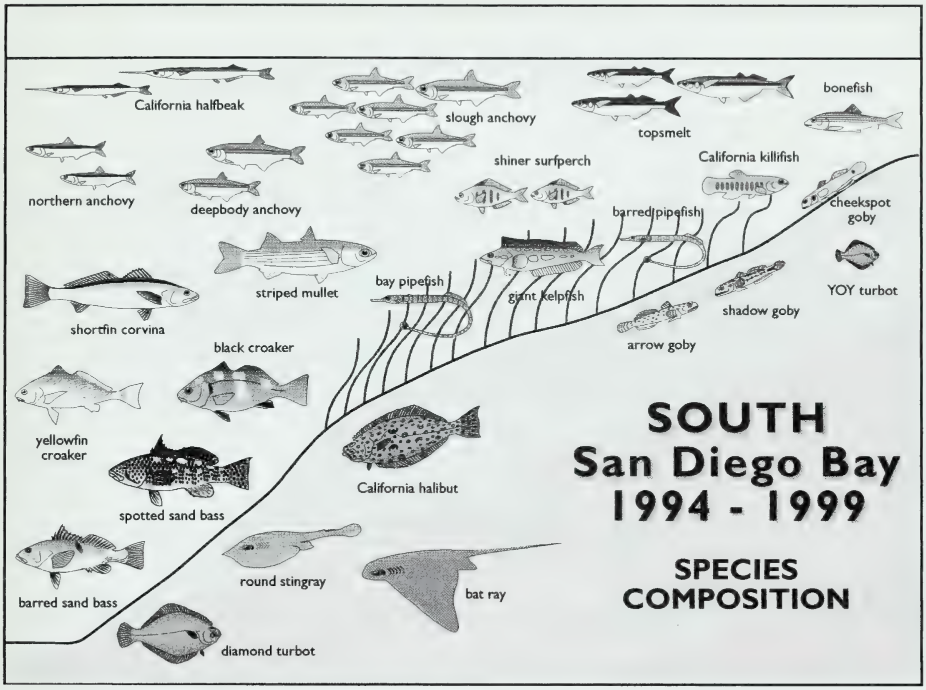
California halfbeak
slough anchovy
topsmelt
bonefish
northern anchovy
deepbody anchovy
shiner surfperch
California killifish
barred pipefish
cheekspot goby
striped mullet
bay pipefish
giant kelpfish
YOY turbot
shadow goby
shortfin corvina
arrow goby
black croaker
yellowfin croaker
spotted sand bass
California halibut
SOUTH
San Diego Bay
1994 - 1999
SPECIES COMPOSITION
round stingray
bat ray
barred sand bass
diamond turbot

Fig. 7. Diagrammatic representation of the common and distinctive species of fish which occurred in the southern portion (South Central and South Ecoregions) of San Diego Bay during the study period of July 1994 to April 1999.

anchovy, and topsmelt. Lowest abundances were generally encountered in the coldest months of the study (January 1995, 1996, 1997, and 1999) with the January 1998 sample containing about 3X the number of fishes as the previous January samples due to a large recruitment of jacksmelt. This abundance pattern was consistent among Stations 1, 2, and 3. However, the southern-most station, 4, exhibited peak abundance in October 1994, October 1996, and April 1998 (Figure 8).

Biomass varied greatly from quarter to quarter and was largely related to the abundance of northern anchovy, round stingrays, bat rays, and spotted sand bass in the catch (Table 7). In the first four years of the study, weights of the catches consistently peaked in the spring (April 1995, 1996, 1997 and 1998) and the summer (July 1995 and 1996) except for July 1997(Figure 9). Significant catches of bat rays in October 1998 (Station 1) and January 1999 (Station 4) greatly disrupted this earlier pattern (Figure 9).

The general seasonal patterns of abundance and distribution of fishes in the northern and southern portions of San Diego Bay are depicted in Figures 10 and 11.

Nursery Area Function

Approximately 70% of all individual fish captured in San Diego Bay during this study were juveniles. In fact, 28 of the 35 most abundant species were represented by over 50% juveniles (Table 8). Of these, ten species were represented by more than 90% juveniles including the most abundant species, northern an-

Table 5. Indigenous Bay/Estuarine species captured in San Diego Bay from July 1994 to April 1999. Note the increasing total abundance of 11 of these 12 species from north to south in the bay.

Scientific name	Common name	Stations, 1994–1999 1	2	3	4	Total	%
Anchoa delicatissima	slough anchovy	4,315	25,526	31,874	35,106	96,821	19.468
Syngnathus leptorhynchus	bay pipefish	701	1,394	1,040	292	3,427	0.689
Syngnathus auliscus	barred pipefish	390	777	598	917	2,682	0.539
Clevelandia ios	arrow goby	51	484	82	1,677	2,294	0.461
Paralabrax maculatofasciatus	spotted sand bass	226	570	334	347	1,477	0.297
Ilypnus gilberti	cheekspot goby	580	582	70	190	1,422	0.286
Quietula ycauda	shadow goby	40	193	84	325	642	0.129
Fundulus parvipinnis	California killifish		29	10	598	637	0.128
Mugil cephalus	striped mullet	8	1	1	510	520	0.105
Anchoa compressa	deepbody anchovy	1	212	23	130	366	0.074
Hypsoblennius gentilis	bay blenny	128	129	9	1	267	0.054
Gillichthys mirabilis	longjaw mudsucker				19	19	0.004
	TOTAL	6,440	29,897	34,125	40,112	110,574	

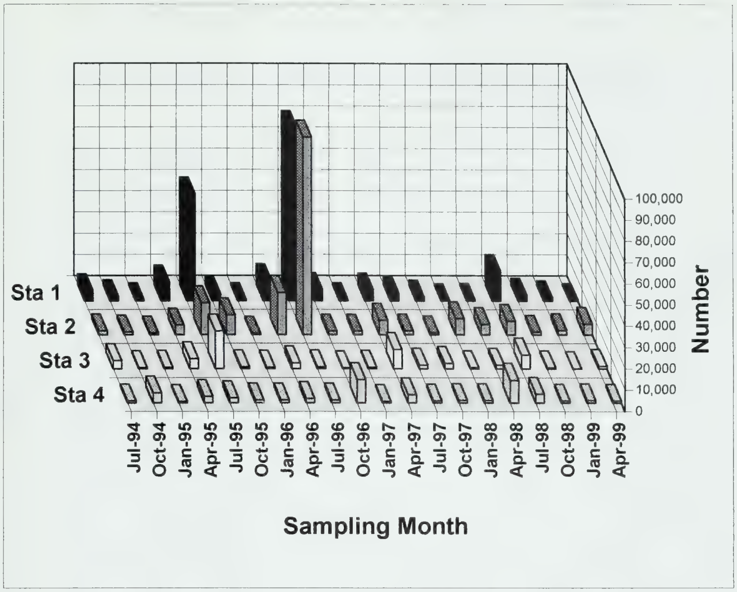

Fig. 8. Abundance of San Diego Bay Fishes by Station over Sampling Months, 1994–1999.

chovy (100% juveniles). This high proportion of juveniles overall in the catch underscores the importance of the San Diego Bay system as an important nursery area for a large number of fish species.

Species Importance

The Index of Community Importance (Table 9) incorporates three significant ecological variables (% Number, %Weight, and %Frequency) for each species and yields a value that is indicative of the importance of each species to the energy flow within the fish component of the bay ecosystem. When all three factors are taken into account, topsmelt rank first among all San Diego Bay fish species with an I.C.I. of 3230. Round stingrays ranked second with an I.C.I. of 2553 followed by northern anchovy with 2271(only 45% frequency within stations by sampling month), slough anchovy with 1790, and spotted sand bass with 1354.

Species Diversity

Species richness (number of species) was generally highest in the northern section of the bay nearest the bay mouth (Station 1–2) being highest at station 1 (Figure 12). H′ diversity which incorporates evenness of relative species abundances was found to be highest in the southern portion of the bay (Station 3–4) peaking at about H′ = 1.5. The higher H′ values in the south bay reflect the lower numerical dominance by one or two species at these stations. Northern anchovy was the numerically dominant species overall at Station 1 in the North Bay while slough anchovy dominated Station 4 in the South Bay.

In the first three years of this study (July 1994 to April 1997), species richness consistently peaked between 40 and 50 species in the spring-summer months (April and July) (Figure 12). This pattern was disrupted in April and July 1997

Table 6. Total abundance of fish species taken from San Diego Bay over the five years of the study, July 1994 to April 1999 by quarterly sampling period.

	MONTHS, 1994-1999																					
COMMON NAME	**Jul-94**	**Oct-94**	**Jan-95**	**Apr-95**	**Jul-95**	**Oct-95**	**Jan-96**	**Apr-96**	**Jul-96**	**Oct-96**	**Jan-97**	**Apr-97**	**Jul-97**	**Oct-97**	**Jan-98**	**Apr-98**	**Jul-98**	**Oct-98**	**Jan-99**	**Apr-99**	**TOTAL**	**%**
northern anchovy	1,697	1		9	52,380	5,461	2	12	147,161		61	3				7	8,366	27	2	429	215,618	43.4
topsmelt	5,043	2,369	1,006	13,045	12,227	4,883	2,300	27,918	5,997	2,177	2,780	10,064	2,853	1,333	547	1,996	7,236	2,129	3,775	5,902	115,580	23.2
slough anchovy	1,813	4,245	159	1,652	15,169	2,530		1,408	15,208	10,250	62	8,879	2,150	4,340	58	14,944	12,846	817	203	88	96,821	19.5
Pacific sardine	1	84	9		2,300	359	2		5,391	3,641		19	566	64	130	11	773	1,357	145	1	14,853	3.0
shiner surfperch	31	44	13	3,305	693	180	5	2,672	550	287	7	2,540	254	23	1	213	123	115	8	193	11,257	2.3
jacksmelt		2	532	2		4	9	1	2	18	160	3	9	4	7,903	15		4	80		8,748	1.8
California grunion									739	404		1,969	1,167			6	1,117	190			5,592	1.1
giant kelpfish	322	395	23	697	605	332	94	868	536	186	41	227	150	33	2	2	69	15	2	89	4,688	0.9
round stingray	89	155	123	481	82	77	121	164	151	414	117	237	241	162	88	72	50	480	379	183	3,866	0.8
bay pipefish	225	255	189	219	131	287	495	248	135	295	183	224	131	18	33	8	69	23	97	162	3,427	0.7
barred pipefish	550	112	100	506	482	134	22	79	117	197	45	83	29	8	10	2	54	2	64	86	2,682	0.5
arrow goby	306	115	23	161	240	145	16	100	239	18	28	2	93	33	280	12	61	19	16	387	2,294	0.5
barred sand bass	81	187	55	386	317	124	25	56	42	19	11	132	97	101	17	26	33	28	44	66	1,847	0.4
spotted sand bass	23	50	57	100	73	43	74	59	77	94	77	77	89	147	68	131	69	88	56	25	1,477	0.3
cheekspot goby	950	62	43	47	5		33		27	2	2	65	40	5	59	12	15	25	20	10	1,422	0.3
California halibut	159	25	29	45	52	24	44	29	46	52	60	45	29	22	44	29	25	33	72	69	933	0.2
shadow goby	1	31	62	9	1	17	13	30	4	58	13	97	6	2	116	27	42	9	60	44	642	0.1
California killifish	5	11	94	21	5	8	13	1	86	17	65		60	24			123	43	58	3	637	0.1
striped mullet		1	9	1		2		1							273	231	1	1			520	0.1
California halfbeak	13	39	1	1		5	61	8	9	49	3	15	24	25			3	149	5		410	0.1
deepbody anchovy	7		22	12	57	10		219	2			29				1	4			3	366	0.1
kelp bass	1	192	4	8	4	3	1	1	8	10	7	5	20	15			1	13	5		298	0.1
black surfperch	4	19		34	97	22		16	30	47		8	1	1			1				280	0.1
bay blenny	26	21	2	15	19	8	4	9	13	41	5	34	10	41	2	1	11	4		1	267	0.1
diamond turbot	33	4	17	26	18	9	3	7	16	16	11	8	20	15	6	15	4	5	12	12	257	0.1
dwarf surfperch	52	14	2	53	49		2	2	12	42				21							249	0.1
queenfish				6	10	42			157							4	5	4			228	0.0
salema		79		8	7	1				25		6	82	10							218	0.0
spotted turbot	13	6	3	9	11	6	13	11	7	4	23	24	13	9	13	1	6	5	21	19	217	0.0
black croaker	3	9	3	21	10	16		6	16	2	1	11	42	5	6	20	1	4		2	178	0.0
bonefish					1										2	115	15	36	5	1	175	0.0
Pacific mackerel				19	5				64	1			37	1	1						128	0.0
yellowfin croaker	9	4	1	2	6	3		16				2	2	11		5	6	38	4	1	110	0.0
spotted kelpfish	52			8	17	2			16				2						1		98	0.0
California tonguefish	12	3		5	2		3	1	18	2	4	10	1	13	5	8	1	3	2	5	98	0.0
specklefin midshipman	9			1	3	1			27		1	9	9	7	1	1	3	4	2	1	79	0.0
fantail sole	9	1	1	5	2	1	2	2	3	1		1		33	1	1	1		6	2	72	0.0
California lizardfish	8		2	17	10			1	15		1	7			1	2	2	2	1		69	0.0
bat ray	1			3	4			5	1								1	27	15		57	0.0
California barracuda	2	1											1	51		1		1			57	0.0
40 additional spp/taxa	97	41	21	39	95	12	8	14	30	7	7	20	7	30	3	9	29	27	16	17	529	0.1
TOTAL	**11,647**	**8,577**	**2,605**	**20,978**	**85,189**	**14,751**	**3,365**	**33,964**	**176,952**	**18,376**	**3,775**	**24,855**	**8,235**	**6,607**	**9,670**	**17,928**	**31,166**	**5,727**	**5,176**	**7,801**	**497,344**	

Table 7. Total biomass (g) of fish species taken from San Diego Bay over the five years of the study, July 1994 to April 1999 by quarterly sampling period.

COMMON NAME	MONTHS, 1994-1999																					
	Jul-94	Oct-94	Jan-95	Apr-95	Jul-95	Oct-95	Jan-96	Apr-96	Jul-96	Oct-96	Jan-97	Apr-97	Jul-97	Oct-97	Jan-98	Apr-98	Jul-98	Oct-98	Jan-99	Apr-99	TOTAL	%
round stingray	12,381	30,696	31,286	61,684	17,442	15,403	31,497	31,268	32,279	33,250	34,497	40,221	36,984	28,559	18,874	11,895	13,982	107,036	67,849	29,985	687,070	24.8
spotted sand bass	7,775	16,747	20,801	34,148	25,781	11,273	25,851	14,555	15,194	25,807	20,252	16,163	17,347	21,454	21,073	27,270	14,930	20,556	17,894	7,335	382,206	13.8
northern anchovy	882	5		7	49,694	18,688	1	20	178,879		2	8				1	9,471	32	13	597	258,297	9.3
bat ray	4,333			13,000	3,902			36,750	484								450	173,398	22,250		254,568	9.2
topsmelt	7,977	16,520	5,897	4,293	18,574	27,166	13,467	8,012	12,486	9,567	13,532	36,868	7,509	9,025	6,225	9,686	10,787	8,142	20,455	5,359	251,547	9.1
slough anchovy	1,552	2,531	139	6,314	39,389	4,750		3,215	26,894	8,146	90	16,476	2,833	2,681	69	40,052	25,989	973	214	153	182,456	6.6
barred sand bass	2,851	4,650	535	15,774	22,494	7,748	1,928	35,562	4,600	2,453	754	2,409	8,157	4,629	267	2,773	1,914	1,779	372	1,282	122,931	4.4
California halibut	23,469	7,463	4,408	3,832	9,932	2,396	10,467	4,645	4,584	4,959	5,347	3,792	1,938	982	8,508	4,928	1,184	1,357	4,339	3,843	112,373	4.0
shiner surfperch	188	544	371	15,863	5,247	2,335	42	22,838	3,958	1,640	221	16,371	1,566	153	40	1,179	687	1,964	187	541	75,933	2.7
Pacific sardine	1	362	75		5,467	2,919	19		18,644	11,783		198	1,837	6,523	9,021	883	1,549	4,248	922	17	64,467	2.3
jacksmelt		365	3,500	1		328	830	113	635	2,850	5,666	312	279	647	20,595	1,096		777	6,429		44,424	1.6
giant kelpfish	2,315	7,168	208	1,898	5,357	5,685	2,564	1,649	5,238	2,940	143	517	793	319	1	0	272	186	0	51	37,303	1.3
diamond turbot	3,009	612	1,622	2,400	2,458	1,781	666	2,483	2,739	1,784	1,246	1,482	2,715	3,002	1,096	1,607	114	1,047	2,675	2,170	36,707	1.3
California grunion									885	1,162		29,380	1,925			101	2,123	480			36,053	1.3
black croaker	133	1,266	20	1,948	2,164	3,094		1,510	1,289	18	242	1,543	1,892	692	1,300	4,264	13	894		475	22,756	0.8
shovelnose guitarfish					4,598							1,997			3,757			10,150			20,502	0.7
Pacific mackerel				3,147	726				8,848	51			5,740	168	500						19,180	0.7
yellowfin croaker	486	258	514	64	877	239		1,500				242	91	2,202		2,358	635	4,952	1,650	400	16,469	0.6
spotted turbot	733	408	36	546	1,482	969	1,064	1,626	938	393	1,331	1,613	847	494	657	20	465	397	1,023	907	15,948	0.6
black surfperch	79	1,091		963	5,155	2,024		460	676	2,891		731	28	91			14				14,202	0.5
shortfin corvina								750	1,089			726	2	440		4,540	3,500	91	800		11,937	0.4
California butterfly ray																1,114	7,500	227	1,600		10,441	0.4
fantail sole	1,622	198	336	729	30	500	393	514	1,331	363		363		320	180	480	160		1,048	470	9,036	0.3
spotted scorpionfish	3,102	352	334	416	908	500		484	30	242	182	363				500		22	459		7,893	0.3
queenfish				137	354	71			5,392							342	25	71			6,392	0.2
grey smoothhound	272	227						968			242			336		1,500	115		737	1,650	6,047	0.2
brown smoothhound								813										4,536			5,349	0.2
specklefin midshipman	78			9	485	63			637		15	1,341	1,185	114	15	40	484	53	1	225	4,744	0.2
jack mackerel									4,095												4,095	0.1
California needlefish	1	1	109	26		133	393	605	182			516	325	474		33	163	501	250	42	3,753	0.1
dwarf surfperch	201	133	22	265	1,716		34	37	84	379				166							3,037	0.1
kelp bass	15	881	65	70	650	79	3	17	228	64	69	80	317	125			100	19	136		2,917	0.1
salema		52		56	111	8				9		182	2,419	4							2,840	0.1
California barracuda	1	1											20	958		150		1,700			2,830	0.1
California corbina																1,100	1,500			150	2,750	0.1
deepbody anchovy	89		349	210	1,044	62		643	4			29				14	67			15	2,527	0.1
California hornshark									2,420												2,420	0.1
California tonguefish	308	47		172	121		91	30	695	30	212	182	20	196	98	9	5	10	43	85	2,354	0.1
bay blenny	304	215	3	87	355	46	3	22	225	195	35	158	235	259	0	1	170	14		2	2,329	0.1
bay pipefish	254	138	683	60	82	151	153	98	131	147	47	83	84	11	9	4	33	39	37	59	2,304	0.1
40 additional spp/taxa	1,613	1,474	455	2,787	3,161	1,660	1,092	1,050	2,077	908	397	474	204	750	848	153	2,069	1,473	1,044	236	23,926	0.9
TOTAL	**76,023**	**94,405**	**71,769**	**170,905**	**229,755**	**110,071**	**90,557**	**172,237**	**337,869**	**112,032**	**84,522**	**174,817**	**97,290**	**85,773**	**93,134**	**118,092**	**100,467**	**347,120**	**152,425**	**56,048**	**2,775,311**	

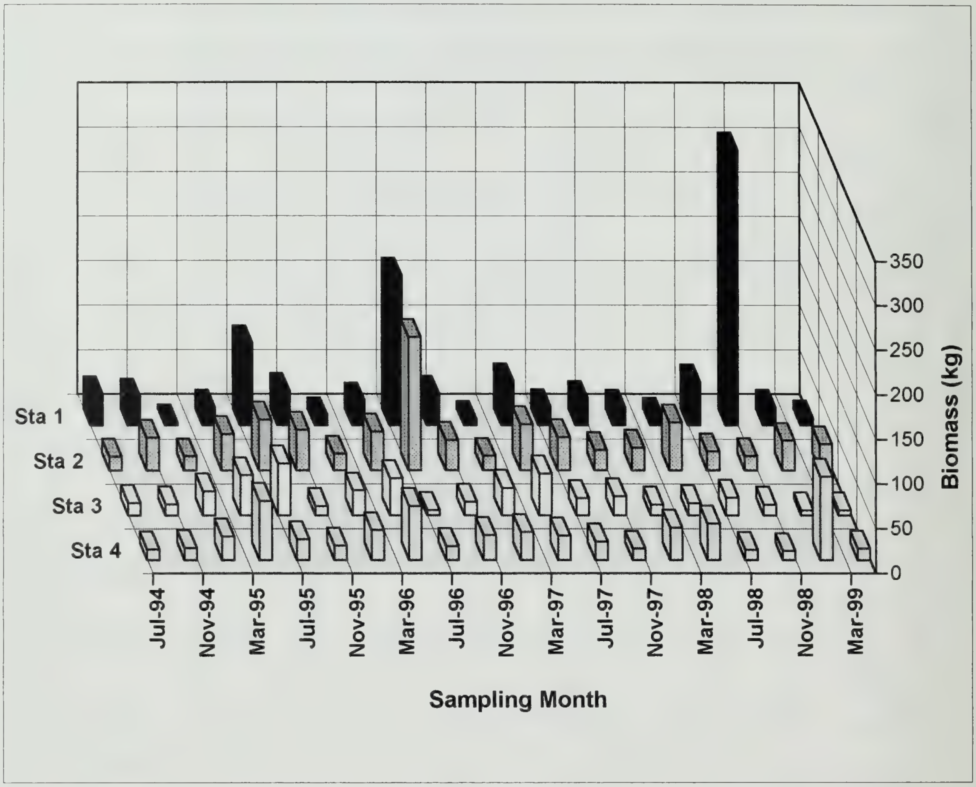

Fig. 9. Biomass (kg) of San Diego Bay Fishes by Station over Sampling Months, 1994–1999.

when only 37 and 35 total species were captured. Within the last two sampling years the April and July catches included only 24 to 37 species. In 1997–1999, the highest number of species was actually taken in October 1997. H′ diversity followed a pattern which was typically the inverse of species richness in the first three years. H′ was typically highest in October and January reflecting the higher evenness of species abundances during these months. The generally lower H′ values in April and July were due to the numerical dominance a few species in these months. Again, this pattern changed starting in 1997 when April and, especially July had relatively high H′ values. The relatively low recruitment of shiner surfperch in April 1997 and the lack of the usual occurrence of large numbers of northern anchovies in July 1997 were primarily responsible for this change. H′ values rose again in July and October 1998 indicating a partial return to the pattern observed in the first three years of the study.

Fish Assemblage Structure

Fish assemblage structure was examined using cluster analysis. The clustering strategy was based on co-occurrences of the species ranking in the top 35 in numerical abundance or in the top 20 in biomass and yielded 11 distinct species and eight site groupings (Figure 13). The species groups reflected the varying abundances and distributions of these species in space and time (Figure 14). Spe-

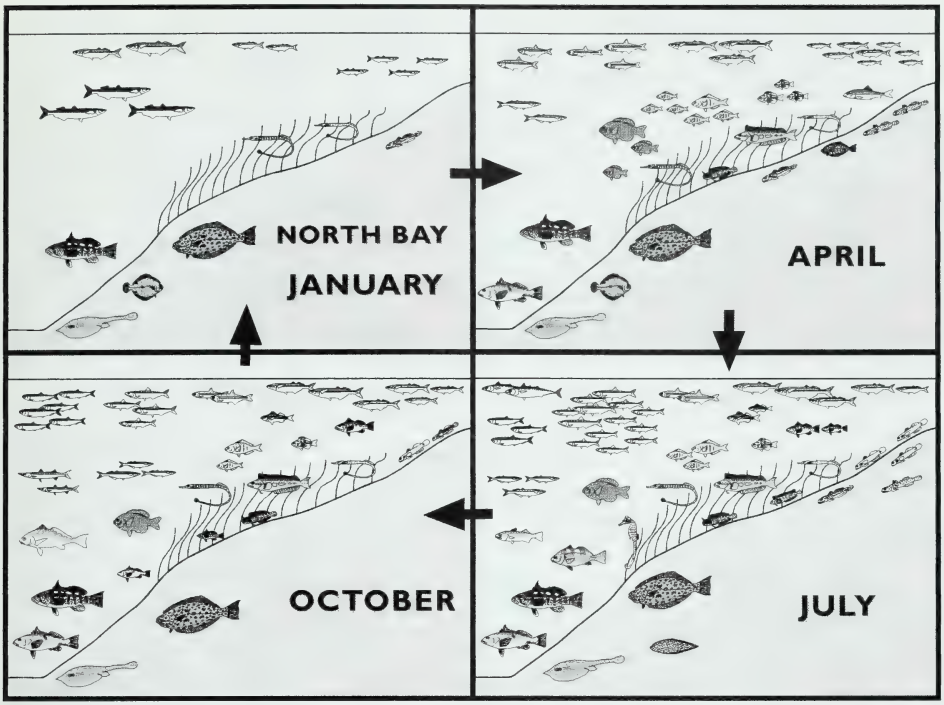

Fig. 10. Diagrammatic representation of the general, seasonal occurrence of the common species of fish occuring in the northern portion (North and North Central) of San Diego Bay during the study period of July 1994 to April 1999.

cies groups which occurred in both the intertidal and nearshore depth strata are characterized as "inshore" below.

Species Group I.—This group contained three species of inshore, wide-spread, resident and summer-seasonal, schooling (midwater) fishes. Topsmelt, California grunion, Pacific sardine, were numerically dominant species, particularly, in the north-central bay during the spring-summer months when large numbers of their young-of-the-year (YOY) occurred. Topsmelt represented the truly resident member of this group which was abundant at all stations in the bay with YOY occurring in highest abundance in spring samples (April). All members of this group also occurred in lower abundance in the midwater regions of the channels.

Species Group II.—This group of three, inshore, summer-seasonal, eelgrass-associated fishes occurred only in the north and north-central portion of the bay. These included the surfperch species, the black surfperch (*Embiotoca jacksoni*), dwarf surfperch (*Micrometrus minimus*), and spotted kelpfish (*Gibbonsia elegans*). Most of the individuals of these species were YOY.

Species Group III.—This small group included two, inshore, north bay, resident, spring-recruiting fishes. YOY of the flatfish, California halibut (*Paralichthys californicus*) inhabited the intertidal areas along with all age groups of the cheekspot goby (*Ilypnus gilberti*).

Species Group IV.—This group of inshore, resident & summer-seasonal, eelgrass-associated fishes included the YOY of kelp bass (*Paralabrax clathratus*),

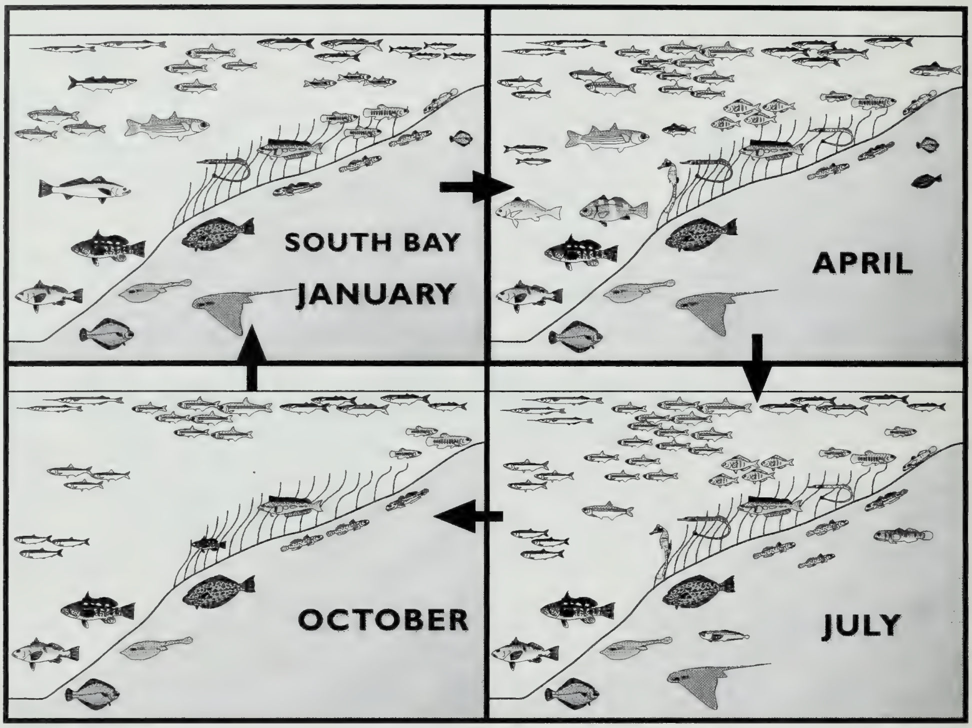

Fig. 11. Diagrammatic representation of the general, seasonal occurrence of the common species of fish occuring in the southern portion (South Central and South Ecoregions) of San Diego Bay during the study period of July 1994 to April 1999.

salema (*Xenistius californiensis*), spotted sand bass (*Paralabrax maculatofasciatus*), and bay blenny (*Hypsoblennius gentilis*). All of these species used the eelgrass beds of the north bay as nursery areas.

Species Group V.—This group included four, inshore, resident, eelgrass-associated fishes which occurred throughout the bay with the greatest abundance in the north, north-central, and south-central portions. Species included the shiner surfperch (*Cymatogaster aggregata*) and the cryptically-colored fishes, the giant kelpfish (*Heterostichus rostratus*), barred pipefish (*Syngnathus auliscus*), and bay pipefish (*Syngnathus leptorhynchus*).

Species Group VI.—This is a group of five, inshore, primarily south bay, resident schooling and benthic species. The numerically dominant, resident fish in the south-central and south bay, the slough anchovy (*Anchoa delicatissima*), clustered in this group along and California halfbeak (*Hyporhamphus rosae*), the deepbody anchovy (*Anchoa compressa*), the California killifish (*Fundulus parvipinnis*) and arrow goby (*Clevelandia ios*).

Species Group VII.—This group included five taxa of inshore, south bay, resident, species which recruited in the winter months and remained abundant into the spring of some years. Included in this group were bonefish (*Albula vulpes*) along with striped mullet (*Mugil cephalus*), jacksmelt (*Atherinopsis californiensis*), shadow goby (*Quietula ycauda*), and YOY of diamond turbot (*Hypsopsetta guttulata*).

Species Group VIII.—A group of three, nearshore and channel, summer-sea-

Table 8. Estimated percent of juveniles in the catch of the top 35 species of fish from San Diego Bay, July 1994–April 1999.

Scientific name	Common name	% juv
Engraulis mordax	northern anchovy	100
Gibbonsia elegans	spotted kelpfish	100
Heterostichus rostratus	giant kelpfish	100
Paralabrax clathratus	kelp bass	100
Paralichthys californicus	California halibut	99
Albula vulpes	bonefish	99
Paralabrax nebulifer	barred sand bass	97
Sardinops sagax	Pacific sardine	96
Mugil cephalus	striped mullet	95
Xenistius californiensis	salema	94
Clevelandia ios	arrow goby	79
Syngnathus auliscus	barred pipefish	78
Syngnathus leptorhynchus	bay pipefish	76
Atherinops affinis	topsmelt	73
Seriphus politus	queenfish	73
Fundulus parvipinnis	California killifish	72
Quietula ycauda	shadow goby	71
Atherinopsis californiensis	jacksmelt	69
Porichthys myriaster	specklefin midshipman	67
Ilypnus gilberti	cheekspot goby	67
Embiotoca jacksoni	black surfperch	66
Leuresthes tenuis	California grunion	66
Umbrina roncador	yellowfin croaker	66
Micrometrus minimus	dwarf surfperch	63
Xystreurys liolepis	fantail sole	61
Urolophus halleri	round stingray	53
Cymatogaster aggregata	shiner surfperch	51
Anchoa delicatissima	slough anchovy	43
Hypsoblennius gentilis	bay blenny	37
Cheilotrema saturnum	black croaker	36
Pleuronichthys ritteri	spotted turbot	35
Anchoa compressa	deepbody anchovy	23
Paralabrax maculatofasciatus	spotted sand bass	22
Hypsopsetta guttulata	diamond turbot	18
	Average % juveniles	69

sonal, schooling fishes, which primarily occurred in the north bay. The most abundant, seasonal species in the study, the northern anchovy (*Engraulis mordax*), clustered in this group along with the highly summer-seasonal species, Pacific mackerel (*Scomber japonicus*) and queenfish (*Seriphus politus*).

Species Group IX.—Clustering designated this group of large, predatory, benthic species which were resident in the nearshore areas and channels of all sections of the bay. This group was represented by the larger size classes of the the spotted sand bass (*Paralabrax maculatofasciatus*) and barred sand bass (*Paralabrax nebulifer*), and all size classes of round stingray (*Urolophus halleri*) and black croaker (*Cheilotrema saturnum*).

Species Group X.—This group was made up of three large carnivores which occupied the nearshore and channel areas in low to moderate numbers throughout the bay, but were most often captured in the south bay. The group included

Table 9. Percent number (%N), percent biomass (%WT), percent frequency of occurrence (%FREQ), and Index of Community Importance (I.C.I.) for the top 50 species (ranked by I.C.I.) of fishes from San Diego Bay, July 1994–April 1999.

RANK	Common Name	%N	%WT	%FREQ	I.C.I.
1	topsmelt	23.24	9.06	100.00	3230.3
2	round stingray	0.78	24.76	100.00	2553.4
3	northern anchovy	43.35	9.31	45.00	2369.7
4	slough anchovy	19.47	6.57	68.75	1790.4
5	spotted sand bass	0.30	13.77	96.25	1354.1
6	barred sand bass	0.37	4.43	96.25	462.1
7	California halibut	0.19	4.05	100.00	423.7
8	shiner surfperch	2.26	2.74	72.50	362.5
9	Pacific sardine	2.99	2.32	40.00	212.4
10	giant kelpfish	0.94	1.34	75.00	171.5
11	bat ray	0.01	9.17	13.75	126.3
12	jacksmelt	1.76	1.60	36.25	121.8
13	diamond turbot	0.05	1.32	86.25	118.5
14	bay pipefish	0.69	0.08	91.25	70.5
15	barred pipefish	0.54	0.06	85.00	50.8
16	California grunion	1.12	1.30	20.00	48.5
17	black croaker	0.04	0.82	52.50	44.9
18	spotted turbot	0.04	0.57	55.00	34.0
19	arrow goby	0.46	0.01	67.50	31.7
20	yellowfin croaker	0.02	0.59	31.25	19.2
21	cheekspot goby	0.29	0.01	61.25	18.0
22	black surfperch	0.06	0.51	21.25	12.1
23	fantail sole	0.01	0.33	27.50	9.4
24	Pacific mackerel	0.03	0.69	11.25	8.1
25	shadow goby	0.13	0.01	53.75	7.5
26	California scorpionfish	0.01	0.28	22.50	6.6
27	specklefin midshipman	0.02	0.17	35.00	6.5
28	California halfbeak	0.08	0.04	53.75	6.5
29	California killifish	0.13	0.05	33.75	6.1
30	bay blenny	0.05	0.08	43.75	6.0
31	shortfin corvina	0.01	0.43	13.75	6.0
32	kelp bass	0.06	0.11	36.25	6.0
33	California needlefish	0.01	0.14	28.75	4.1
34	deepbody anchovy	0.07	0.09	23.75	3.9
35	shovelnose guitarfish	0.00	0.74	5.00	3.7
36	California tonguefish	0.02	0.08	28.75	3.0
37	queenfish	0.05	0.23	10.00	2.8
38	gray smoothhound	0.00	0.22	12.50	2.8
39	striped mullet	0.10	0.08	13.75	2.6
40	salema	0.04	0.10	17.50	2.6
41	dwarf surfperch	0.05	0.11	15.00	2.4
42	California butterfly ray	0.00	0.38	5.00	1.9
43	California lizardfish	0.01	0.06	21.25	1.6
44	bonefish	0.04	0.06	15.00	1.5
45	California barracuda	0.01	0.10	8.75	1.0
46	yellowfin goby	0.01	0.03	20.00	0.7
47	spotted kelpfish	0.02	0.01	17.50	0.6
48	Pacific seahorse	0.00	0.02	27.50	0.6
49	brown smoothhound	0.00	0.19	2.50	0.5
50	staghorn sculpin	0.01	0.02	20.00	0.4

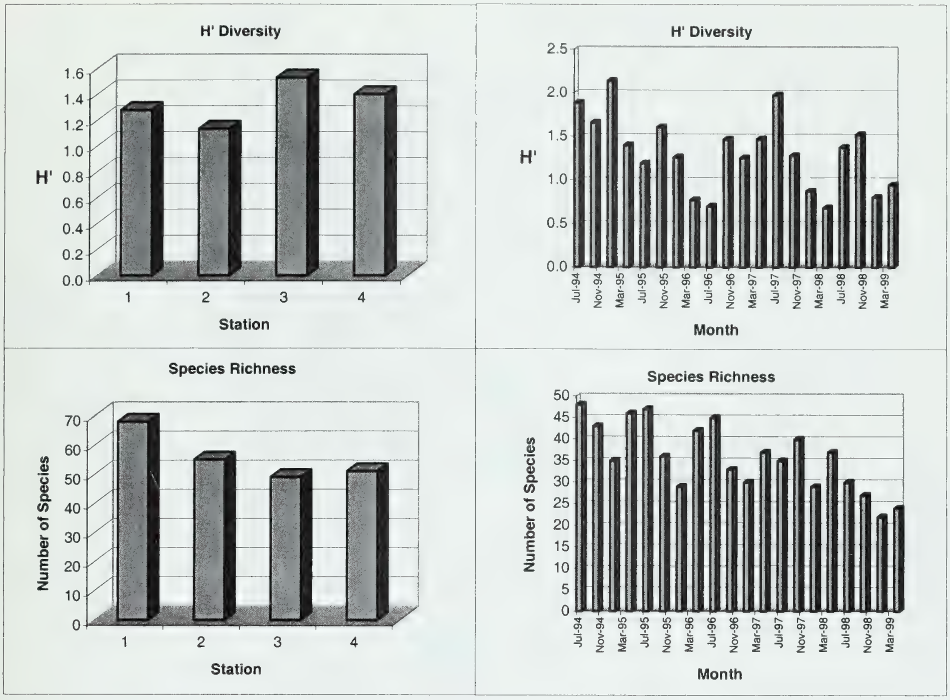

Fig. 12. Number of species (species richness) and Shannon-Weiner Diversity (H′) of fishes in San Diego Bay by station and sampling month, July 1994–April 1999.

resident (Shortfin corvina, *Cynoscion parvipinnis* and bat rays, *Myliobatis californicus*) and summer seasonal (yellowfin croaker, *Umbrina roncador*) species.

Species Group XI.—This group included four species of resident, benthic, flatfish species which occurred throughout the bay primarily in the channels. Included in this group were the larger juveniles and adults of California halibut (*Paralichthys californicus*) and diamond turbot (*Hypsopsetta guttulata*) which were distributed in all depth strata. The remaining two species (spotted turbot (*Pleuronichthys ritteri*) and California tonguefish (*Symphurus atricauda*)) mainly occupied the channels of the north bay.

Relationship of PC factors to Fish Distribution and Abundance

Canonical correlation was utilized to estimate the relationship of the four prominent PC factors of station (as a surrogate for distance from the mouth of the bay), depth, temperature, and salinity to the individual station abundances ($\log_{10}(x + 1)$) of the 35 most abundant species. These four PC factors accounted for nearly 88% ($R^2 = 0.875$) of the variance in individual species abundance among stations over sampling month (Table 10). This extremely high R^2 value served to underscore the great influence which relatively few environmental factors can have on the distribution and abundance of fishes over time.

As a result of this highly significant relationship, the eleven species groups determined through cluster analysis discriminated very well among the first three, significant discriminate roots (Figure 15).

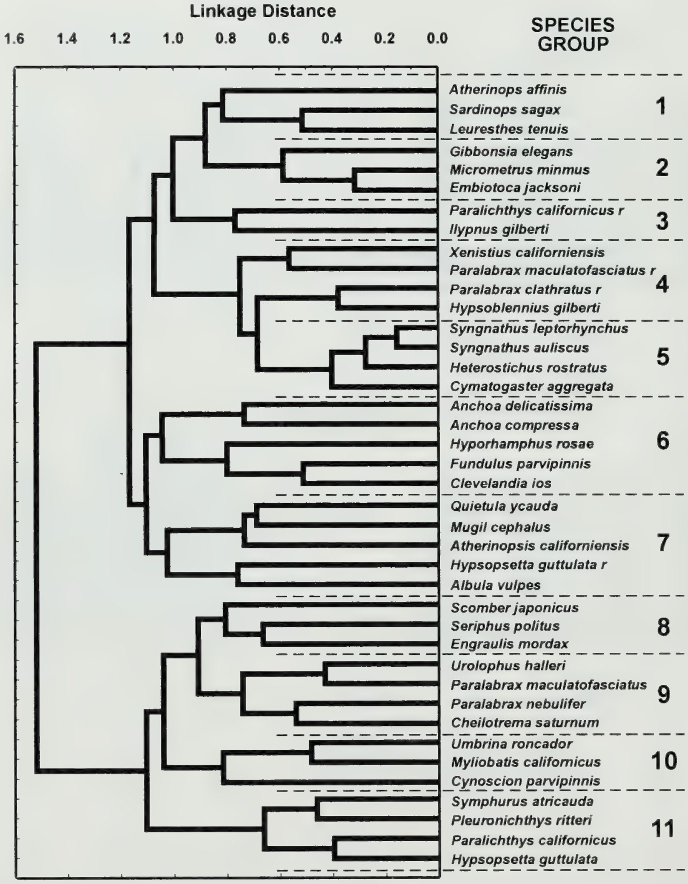

Fig. 13. Results of the cluster analysis of the top 40 fish species or recruits based on co-occurrences in station/ depth strata samplescollected from July 1994 to April 1999 in San Diego Bay (r = new recruits of the species).

Standing Stock Estimates

All Fish Species.—Over the entire bay for all five years, the total best estimate of numerical density was 1.75 indiv./m^2 (Table 11). Based on a surface area of approximately 4858 ha, San Diego Bay, on average, contained almost 85 million fish during this time. Most of the individuals are made up of northern anchovies (42 million), but there were also, again on average, almost 18 million slough anchovies, 10 million topsmelt, 3 million sardines, 3 million arrow gobies, and nearly 2 million shiner surfperch. Among the most common, higher-level carnivores, there are about 280,000 round stingrays, 169,000 spotted sand bass, 133,000, barred sand bass, and almost 80,000 California halibut.

The total best estimate of biomass density was 7.05 g/m^2 (Table 12). Again, based on area, during 1994–1999, San Diego Bay, on average, contained about 340 metric tons (mt) of fish. On a yearly basis most of the biomass was made up of northern anchovies (52 mt), spotted sand bass (50 mt), round stingrays (49 mt), topsmelt (37 mt), and slough anchovy (36 mt).

The best estimate process yielded an overall biomass density (7.05 g/m^2) which

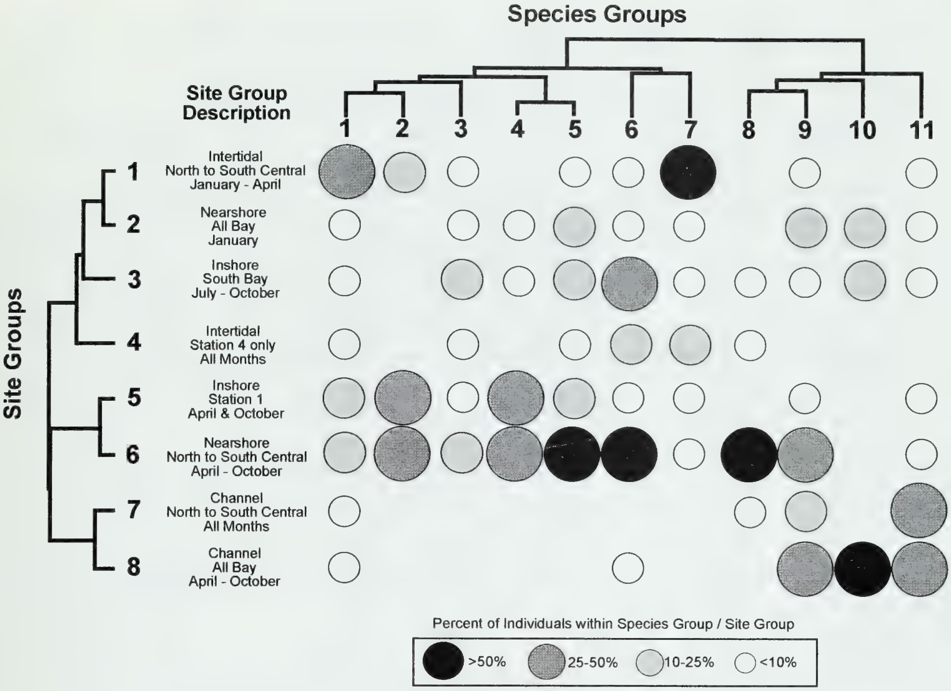

Fig. 14. Two-way table depicting the relative abundances of species within site groups derived by cluster analysis. Circles represent abundances of the individuals within the species of a species group at each of the eight site groups. Site groups are described according to there distribution in space over time.

Table 10. Results of canonical correlation analysis for four PC factors (Station, Depth, Temperature, Salinity) versus log-abundance of the 35 most abundant individual species taken in each quarterly sampling from San Diego Bay, July 1994–April 1999.

Chi-square tests with successive roots removed					
Root removed	Canonical R	Canonical R-sqr.	Chi-sqr.	df	p
0	0.935	0.875	923.474	160	<0.0001
1	0.835	0.698	473.408	117	<0.0001
2	0.642	0.412	214.440	76	<0.0001
3	0.607	0.368	99.480	37	<0.0001

Canonical weights, physical-chemical factors			
	Root 1	Root 2	Root 3
STA	0.106	0.952	−0.037
DEPTH	−0.992	0.184	0.071
TEMP	−0.032	0.097	0.664
SAL	0.053	0.040	−1.053

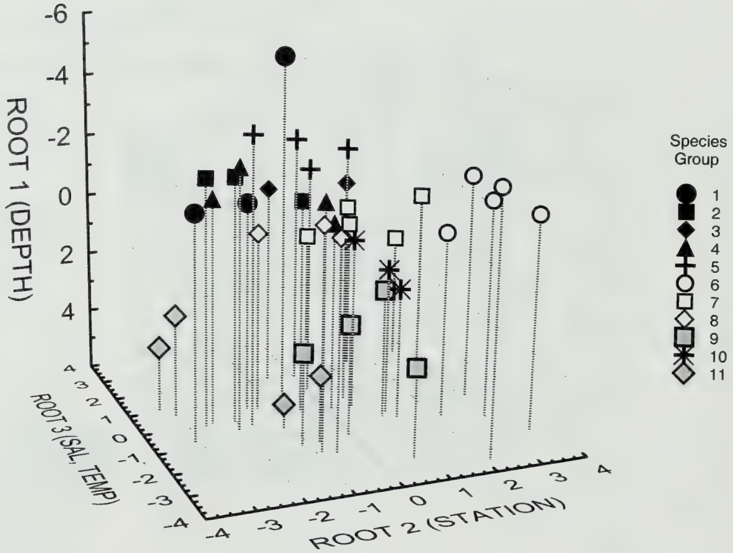

Fig. 15. Three-dimensional plot of species within species groups by three significant discriminant roots.

was over three times higher than that (2.03 g/m^2) derived from taking the simple mean of individual gear densities. This discrepancy is due to the artificial bias introduced when catches from gears with dramatically different efficiencies are simply averaged quantitatively with no regard to quality of the estimate.

Forage Species.—Forage species are defined herein as those which are accessible to diving avian predators, particularly terns. Forage species are typically silvery-sided, schooling fishes which spend a lot of their time near the surface of the water overall depth strata. Of all the species captured during this study, eleven qualified as significant forage. These species were northern anchovy, topsmelt, slough anchovy, jack smelt, Pacific sardine, shiner surfperch, Pacific mackerel, California grunion, deepbody anchovy, California halfbeaks, and striped mullet (juveniles).

Over all Ecoregions for all five years, these eleven forage species averaged 3.15 (±1.28) g/m^2. Based on surface area, San Diego Bay contained, on average about 139 metric tons (mt) of these important forage species. The standing stock ranged from a low of about 22 mt in the South Ecoregion to a high of 43 mt in the North Ecoregion (Table 13).

In the North Ecoregion, northern anchovy ranked first among the forage species in contributing an average of nearly 14 mt over the study period followed by topsmelt (10.1 mt), Pacific sardine (7.9 mt), and jacksmelt (4.9 mt). The standing stock of the North-Central region was dominated, again, by northern anchovy (13.0 mt), followed by slough anchovy (8.5 mt) and topsmelt (6.3 mt). Slough anchovy (22.6 mt), topsmelt (5.5 mt), and shiner surfperch (5.2 mt) made up the bulk of the forage in the South-Central Ecoregion while slough anchovy (10.2 mt), topsmelt (5.4 mt) and jack smelt (3.3 mt) dominated the South Ecoregion.

Based on a conservative, hypothetical, ecological efficiency of 1%, overall, San Diego Bay has the potential to support about 1.4 mt of terns.

Table 11. Best estimate of numerical densities (No./m^2) and estimated stock size for the most abundant fish species taken from San Diego Bay, as a whole, from July 1994 to April 1999.

	BEST ESTIMATE OF DENSITY (No/m^2)				
COMMON NAME		**STRATA**		**WTD**	**STOCK**
	I	**N**	**C**	**MEAN**	**Est. No.**
northern anchovy	0.014	1.434	0.148	0.876	42,533,776
slough anchovy	0.067	0.566	0.109	0.368	17,868,784
topsmelt	1.750	0.212	0.049	0.210	10,201,738
Pacific sardine	0.002	0.074	0.058	0.065	3,148,496
arrow goby	1.414	0.005	0.000	0.059	2,876,938
shiner surfperch	0.003	0.067	0.000	0.039	1,873,634
California grunion	0.005	0.035	0.002	0.021	1,006,501
shadow goby	0.485	0.002	0.000	0.020	992,253
bay pipefish	0.033	0.021	0.000	0.013	651,421
giant kelpfish	0.004	0.023	0.000	0.013	648,728
jacksmelt	0.266	0.003	0.002	0.013	624,777
cheekspot goby	0.254	0.004	0.000	0.013	609,349
barred pipefish	0.034	0.016	0.000	0.011	513,060
round stingray	0.001	0.007	0.004	0.006	277,119
spotted sand bass	0.000	0.006	0.001	0.003	169,452
barred sand bass	0.000	0.004	0.002	0.003	133,803
California halibut	0.015	0.001	0.001	0.002	78,725
deepbody anchovy	0.000	0.002	0.000	0.001	63,451
bay blenny	0.006	0.002	0.000	0.001	58,865
kelp bass	0.000	0.002	0.000	0.001	47,300
queenfish	0.000	0.001	0.001	0.001	45,933
California killifish	0.017	0.000	0.000	0.001	32,785
salema	0.000	0.001	0.000	0.001	32,514
black surfperch	0.000	0.001	0.000	0.001	26,967
Pacific mackerel	0.000	0.001	0.000	0.001	26,116
diamond turbot	0.006	0.000	0.000	0.000	24,004
California halfbeak	0.003	0.000	0.000	0.000	21,394
dwarf surfperch	0.001	0.001	0.000	0.000	20,286
bonefish	0.002	0.000	0.000	0.000	11,196
California barracuda	0.000	0.000	0.000	0.000	10,828
black croaker	0.000	0.000	0.000	0.000	10,220
striped mullet	0.004	0.000	0.000	0.000	9,221
47 additional species	0.009	0.003	0.001	0.003	127,138
TOTAL	**4.396**	**2.494**	**0.378**	**1.745**	**84,776,769**

Fisheries Species.—Eight species of fish were captured that can be characterized as fisheries species important to the recreational and/or commercial (RC) catch in southern California waters. Ranked according to mean biomass density, these species were northern anchovy, spotted sand bass, Pacific sardine, California halibut, barred sand bass, Pacific mackerel, shortfin corvina, and yellowfin croaker.

Over all Ecoregions for all five years, these eight, RC species averaged 2.40 (±1.14) g/m^2. Based on a surface area of approximately 4858 ha, San Diego Bay contains, on average about 104 metric tons (mt) of these important RC species. The standing stock of RC species ranged from a low of about 15 mt in the South Ecoregion to a high of 31 mt in the North Ecoregion (Table 13).

In the North Ecoregion, northern anchovy ranked first among the RC species in contributing an average of nearly 14 mt over the study period followed by

Table 12. Best estimates of biomass densities (g/m^2) and estimated stock size for the most abundant fish species taken from San Diego Bay, as a whole, from July 1994 to April 1999.

COMMON NAME	BEST ESTIMATE OF DENSITY (g/m^2)			WTD MEAN	STOCK Est. No.	STOCK metric tons
	STRATA					
	I	N	C			
northern anchovy	0.010	1.628	0.356	1.067	51,836,937	51.8
spotted sand bass	0.007	1.638	0.253	1.033	50,180,537	50.2
round stingray	0.051	1.284	0.714	1.012	49,181,019	49.2
topsmelt	0.675	1.054	0.330	0.756	36,745,334	36.7
slough anchovy	0.073	0.984	0.475	0.749	36,385,765	36.4
bat ray	0.000	0.540	0.303	0.426	20,680,619	20.7
Pacific sardine	0.009	0.294	0.301	0.286	13,878,325	13.9
shiner surfperch	0.043	0.481	0.001	0.276	13,424,822	13.4
shovelnose guitarfish	0.000	0.423	0.029	0.252	12,262,405	12.3
jacksmelt	0.006	0.200	0.216	0.198	9,623,670	9.6
California grunion	0.059	0.208	0.003	0.122	5,944,893	5.9
California halibut	0.031	0.093	0.159	0.117	5,660,609	5.7
barred sand bass	0.006	0.075	0.181	0.113	5,511,344	5.5
giant kelpfish	0.034	0.180	0.004	0.106	5,132,391	5.1
Pacific mackerel	0.000	0.112	0.044	0.081	3,931,394	3.9
shortfin corvina	0.000	0.058	0.051	0.053	2,569,953	2.6
black surfperch	0.003	0.074	0.001	0.043	2,082,049	2.1
yellowfin croaker	0.001	0.055	0.014	0.037	1,779,889	1.8
diamond turbot	0.083	0.014	0.057	0.033	1,610,660	1.6
queenfish	0.000	0.041	0.002	0.024	1,186,484	1.2
black croaker	0.000	0.019	0.034	0.024	1,167,441	1.2
grey smoothhound	0.003	0.023	0.013	0.018	898,173	0.9
jack mackerel	0.000	0.029	0.000	0.016	798,093	0.8
California butterfly ray	0.000	0.019	0.013	0.016	781,311	0.8
California needlefish	0.003	0.020	0.008	0.015	708,700	0.7
California barracuda	0.000	0.008	0.024	0.014	673,435	0.7
spotted turbot	0.000	0.005	0.026	0.013	628,138	0.6
salema	0.000	0.020	0.000	0.011	548,458	0.5
Calfornia corbina	0.000	0.019	0.000	0.011	535,960	0.5
deepbody anchovy	0.001	0.017	0.000	0.010	464,102	0.5
bay blenny	0.013	0.014	0.000	0.008	409,919	0.4
striped mullet	0.004	0.011	0.004	0.008	384,765	0.4
46 additional species	0.265	0.110	0.067	0.099	4,819,018	4.8
TOTAL	**1.380**	**9.749**	**3.684**	**7.049**	**342,426,611**	**342.4**

Pacific sardine (7.9 mt), and spotted sand bass (4.3 mt). The standing stock of the North-Central region was dominated, again, by northern anchovy (13.0 mt), followed by spotted sand bass (11.4 mt) and barred sand bass (1.3 mt). Spotted sand bass (19.4 mt), Pacific sardine (2.8 mt), and California halibut (2 mt) made up the bulk of the fisheries standing stock in the South-Central Ecoregion while spotted sand bass (19.4 mt), Pacific sardine (2.8 mt) and yellowfin croaker (0.8 mt) dominated the South Ecoregion.

Southern Species Unique to San Diego Bay

During the study period eight fish species were taken that can be described as southern or "Panamic Province" species including California halfbeaks (*Hyporhamphus rosae*), bonefish (*Albula vulpes*), California needlefish (*Strongylura exilis*), shortfin corvina (*Cynoscion parvipinnis*), Pacific seahorse (*Hippocampus in-*

Table 13. Best estimates of biomass densities and standing stocks for forage species only and fisheries species only. Estimates are for each depth strata within each Ecoregion of the San Diego Bay.

FORAGE FISH SPECIES

	BEST ESTIMATE OF DENSITY (g/m^2) STRATA						
ECOREGION	**I**	**N**	**C**		**WTD MEAN**	**STAND. STOCK (kg)**	**mt**
NORTH	0.8976	8.5278	2.4428		4.3337	42,557	43
NORTH-CENTRAL	1.0586	6.4966	2.9132		4.1821	33,792	34
SOUTH-CENTRAL	0.8767	2.5911	1.2028		2.0399	40,899	41
SOUTH	0.7618	2.3416	0.3697		2.0454	21,763	22
				TOTAL		**139,011**	**139**

RECREATIONAL/COMMERCIAL FISH SPECIES

	BEST ESTIMATE OF DENSITY (g/m^2) STRATA						
ECOREGION	**I**	**N**	**C**		**WTD MEAN**	**STAND. STOCK (kg)**	**mt**
NORTH	0.08256	5.98068	2.01888		3.18991	31,325	31
NORTH-CENTRAL	0.08203	6.47010	1.98423		3.59375	29,038	29
SOUTH-CENTRAL	0.08484	1.85872	0.90180		1.46101	29,293	29
SOUTH	0.01123	1.52618	0.68564		1.37157	14,594	15
				TOTAL		**104,249**	**104**

gens), California butterfly ray (*Gymnura marmorata*), banded guitarfish (*Zapteryx exasperata*), and red goatfish (*Pseudupeneus grandisquamous*). In addition, four more southern species (green jack, *Caranx caballus;* middling thread herring, *Opisthonema medirastre;* Pacific sierra, *Scomberomorus sierra;* scalloped hammerhead, *Sphyrna lewini*) were collected by gill nets in the Ocean Resource Enhancement and Hatchery Program (OREHP) sampling program conducted by Mike Shane of Hubbs-Sea World Research Institute in the same general time period. All of these species are commonly encountered further south in the Eastern Subtropical and Tropical Pacific. Southern California is listed as the extreme northern end point of the geographical ranges of each of these species. In fact, the occurrence of the single specimen of the red goatfish represented the first record of this species recorded in California waters. The southern portion of San Diego Bay undoubtedly acts as a refuge for these warm water species. Three of these, the California halfbeak, California needlefish and Pacific seahorse were encountered throughout the study period (Figure 16) while the remaining five occurred in greatest abundance during and just after the El Niño evident of 1997–98. Bonefish recruited heavily into the southern sections of the bay beginning in January 1998 and peaked April 1998. Bonefish leptocephalus larvae were captured in the intertidal zones in January and April 1998. These leptocephali metamorphosed into juveniles which were abundant in July and October of the same year.

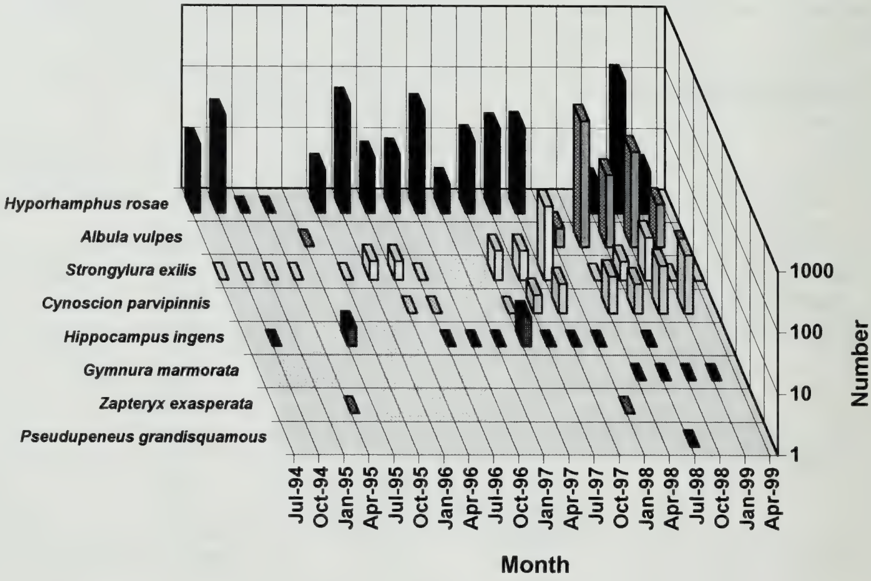

Fig. 16. Abundance of "Panamic Province" or southern species captures in San Diego Bay from July 1994 to April 1999.

Effects of 1997–98 El Nino

The greatest, detectable impact of the 1997–98 El Niño event on the fish assemblages of San Diego Bay was the generally low abundance of schooling, planktivorous species, including northern anchovy, topsmelt, slough anchovy, sardine, and shiner surfperch (the five most abundant species). In fact, the northern anchovy was virtually absent during 1997. Of the most abundant schooling fishes, topsmelt and slough anchovy seemed to be least affected by the El Niño event. Overall, the abundance of these planktivorous species was significantly and negatively correlated ($\log(n + 1)$, $r = -0.86$, $df = 4$, $p < 0.05$) with summer-fall (July–October) surface water temperature over the entire 1994–1999 sampling period.

The quantitative impact of the El Niño on the total number of fishes in San Diego Bay can be approximated using the regression model:

$$N = 7232.12T - 113072;$$

where N = predicted number and T = mean surface temperature. This equation was based on the relationship between abundance of planktivorous species and surface water temperature for the non- El Niño years of the study. Based on this equation, the total catch of all species in San Diego Bay was 50,000 to 55,000 individuals lower in July and October 1997 than would be predicted for a "normal" temperature year.

Another important effect that can probably be attributed to the ENSO event was the recruitment and/or occurrence of the southern species mentioned previously.

Discussion

A total of 78 species of fish were captured in the five years of sampling in San Diego Bay. This total approaches the 89 species predicted from the species-area relationship developed by Horn and Allen (1976). A number of relatively rare, large, and mobile species were undoubtedly missed by this quantitative sampling protocol. The aforementioned OREHP gill net survey (June 1996 through August 1999) yielded eight additional species which were not taken in the current sampling program. The addition of these species (green jack, *Caranx caballus;* pile surfperch, *Damalichthys vacca;* middling thread herring, *Opisthonema medirastre;* white surfperch, *Phanerodon furcatus;* Pacific sierra, *Scomberomorus sierra;* scalloped hammerhead, *Sphyrna lewini;* angel shark, *Squatina californica;* leopard shark, *Triakis semifasciata*) brings the total up to 86 species, even closer to the predicted number of 89 species.

Two, introduced species of Japanese gobies were also captured during the study. The yellowfin goby (*Acanthogobius flavimanus*) was well represented in the samples (n = 34) while a single specimen of the chameleon goby (*Tridentiger trigonocephalus*) was captured in the eelgrass bed in the South-Central Ecoregion (Station 3).

Species richness by station in San Diego Bay was comparable, if not higher than values obtained from other southern California bays, estuaries, and harbors. The northern San Diego Bay stations 1 and 2 (No. spp = 69 and 55) had similar species richness to multiple-gear sampling studies in Los Angeles Harbor and Lower Newport Bay. Allen et al. (1983) captured 65 fish species in the Cabrillo Beach area of western Los Angeles Harbor in 1979. Marine Ecological Consultants (1988) reported 69 fish species in the area covering most of outer Los Angeles Harbor in 1986–87. Allen (1976) sampled a total of 65 species from Newport Bay in 1974–75 in a sampling strategy that included stations from throughout the upper and lower bay.

The southern San Diego Bay stations yielded slightly higher species richness (Station 3, 49 species; Station 4, 52 species) than comparable studies in two other bay/ estuaries in southern California, Mugu Lagoon and upper Newport Bay. Onuf and Quammen (1983) caught a total of only 28 fish species from the small, shallow embayment of Mugu Lagoon. Horn and Allen (1981) reported 46 species captured in a comparable, multiple-gear sampling design in Upper Newport Bay in 1978. Furthermore, Allen (1988) reported 41 species from upper Newport Bay in 1986–87.

Total Shannon-Weiner diversity (H′) for the San Diego Bay stations in 1994–99 ranged from values of 2.05 to 2.32. These H′ values were intermediate to the somewhat lower values reported from upper Newport Bay (1.71 from 1978; 1.94 from 1986–87) and the slightly higher values in Los Angeles Harbor and lower Newport Bay (Cabrillo, H′ = 2.39; outer LA Harbor, H′ = 2.69; lower Newport Bay, H′ = 3.09). The lower H′ values in upper Newport Bay reflect the numerical dominance of a single species, the topsmelt in the catches. The intermediate values of the San Diego Bay stations were the result of numerical dominance of three species, northern anchovy, slough anchovy and topsmelt.

The fish assemblages of San Diego Bay represent a blend of those normally associated with harbors and bay/estuaries within the Southern California Bight

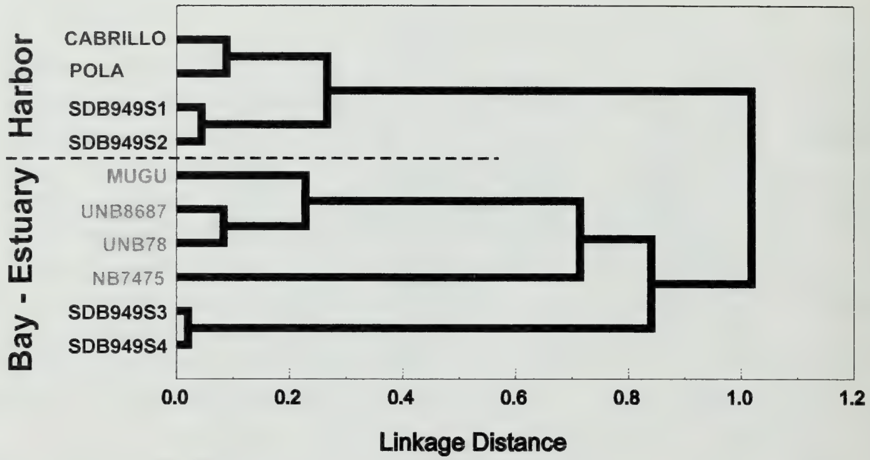

Fig. 17. Cluster of Southern Californian harbor (H), bay and estuarine (BE) habitats based on fish faunal relationships.(Cabrillo = Cabrillo Beach, Los Angeles Harbor; POLA = Port of Los Angeles; Mugu = Mugu Lagoon; NB7475 = Newport Bay study 1974–75; UNB = upper Newport Bay study 1978; UNB8687 = upper Newport Bay study 1986–87; SDB9499S = Present study for stations 1–4).

(Allen, 1985). San Diego Bay stations 1 and 2 cluster with the fish assemblages from previous, comparable studies in southern California harbors (Figure 17), while stations 3 and 4 are more closely associated with the assemblages in the bay/estuaries of southern California. Therefore, San Diego Bay represents a large, unique environment within the Southern California Bight combining elements of two major types of habitats, namely harbor-nearshore soft bottom (HNSB) and bay/estuary (BE) (cf. Allen, 1985).

Allen (1980) conducted the only comparable study utilizing the best estimate process in upper Newport Bay in 1978. Using a similar sampling design, Allen (1980) calculated an overall biomass density of 4.1 g/m^2 for the littoral (intertidal) fish assemblages in upper Newport Bay. This value was about two-thirds of the value of 6.3 g/m^2 derived from the best estimate process in the same study. It is important to note that the overall biomass density estimated herein for San Diego Bay (7.05 g/m^2) exceeded even that from the widely acknowledged, highly productive environment of upper Newport Bay.

Within individual Ecoregions of San Diego Bay, the intertidal areas contained, in general, the highest numerical densities with the North-Central and South regions with best estimates of over 6 indiv./m^2 overall. This was undoubtedly due to the large number of juvenile fishes which recruit to and occupy these warm, productive areas, particularly in the spring. The nearshore habitat supported, by far, the highest biomass densities of fish over the study period. The highest densities were recorded in the North and North-Central ecoregions due primarily to large catches of northern anchovy and spotted sand bass in the summer. The relatively high biomass density found in the South Ecoregion was due mainly to large catches of round stingrays, spotted sand bass, and slough anchovies.

In summary, the fish assemblages of San Diego Bay were found to be diverse, abundant, seasonal, and highly productive particularly for young-of-the-year fishes. The bay itself presents a unique combination of harbor, nearshore soft bottom, and bay/estuarine habitats which each contribute unique sets of species to the overall assemblage. One of these is a group of 12 species which are indigenous to the bays and estuaries of southern California. South San Diego Bay represents a crtical habitat for these unique bay/estuarine species whose habitats have disappeared at an alarming rate during the last half century. The extensive shallow water habitat and eelgrass beds also support a very high standing stock of mid-water, schooling fishes, such as northern anchovies, slough anchovies and topsmelt which, in turn, serve as an important forage resource for both marine birds and larger predatory fishes. In addition, the generally warm and hypersaline waters of south San Diego Bay offer a warm water refuge for a number of southern, "Panamic" province fish species making it unique among all other southern California embayments.

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An evaluation of the distribution and abundance of Common Ravens at Joshua Tree National Park

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Abstract.—We located and evaluated data from the past 100 years to assess the historical and contemporary abundance and distribution of Common Ravens (*Corvus corax*) at and near Joshua Tree National Park in southern California. We found evidence to support the hypothesis that numbers and distribution of this species have increased in the park in the last 50 years. Increases in raven numbers pose a potential threat to populations of Desert Tortoise (*Gopherus agassizii*), as juvenile tortoises are known prey of the Common Raven. We obtained additional data that support the hypotheses that raven densities may be higher in the Mojave Desert than the Colorado Desert, and that densities appear to be lower in regions with few roads. Some of the largest concentration areas for ravens are found at landfills in the Mojave Desert.

The Common Raven (*Corvus corax*) is native to the deserts of southern California but its abundance in the Mojave Desert has grown substantially in recent years. An analysis of Breeding Bird Survey (BBS) data for the Sonoran and Mojave Deserts (Boarman and Berry 1995) showed that raven populations increased 450–1000% over a recent 24-year period. Such increases have raised concerns among wildlife biologists and resource managers because ravens are known to prey on juvenile Desert Tortoises (*Gopherus agassizii*), a species federally-listed as Threatened in the Southwest (U.S. Fish and Wildlife Service 1994). Increases in Common Raven densities in desert areas have been implicated as contributing to the decline of some Desert Tortoise populations (Bureau of Land Management 1990, Boarman 1993, U.S. Fish and Wildlife Service 1994). Ravens prey on avian species that are declining, as well. This includes predation of eggs of the California condor (*Gymnogyps californianus;* Snyder et al. 1986), of the state- Endangered California least tern (*Sterna antillarum browni;* Avery et al. 1995), and of the greater sandhill crane (*Grus canadensis tabida;* Littlefield and Thompson 1987), a California state-listed Threatened species. Ravens prey on eggs and chicks of the western snowy plover (*Charadrius alexandrinus nivosus*) on the California coast (pers. comm. Gary Page, Point Reyes Bird Observatory), a species whose coastal nesting populations are federally-listed as Threatened.

Increases in Common Raven numbers have been attributed to an increase in human occupation in the region (Boarman and Berry 1995). One anthropogenic resource used by ravens in the deserts of California is landfills. Ravens use landfills as foraging sites, including the consumption of organic materials exposed along the active face of landfills (FaunaWest Wildlife Consultants 1991). Imple-

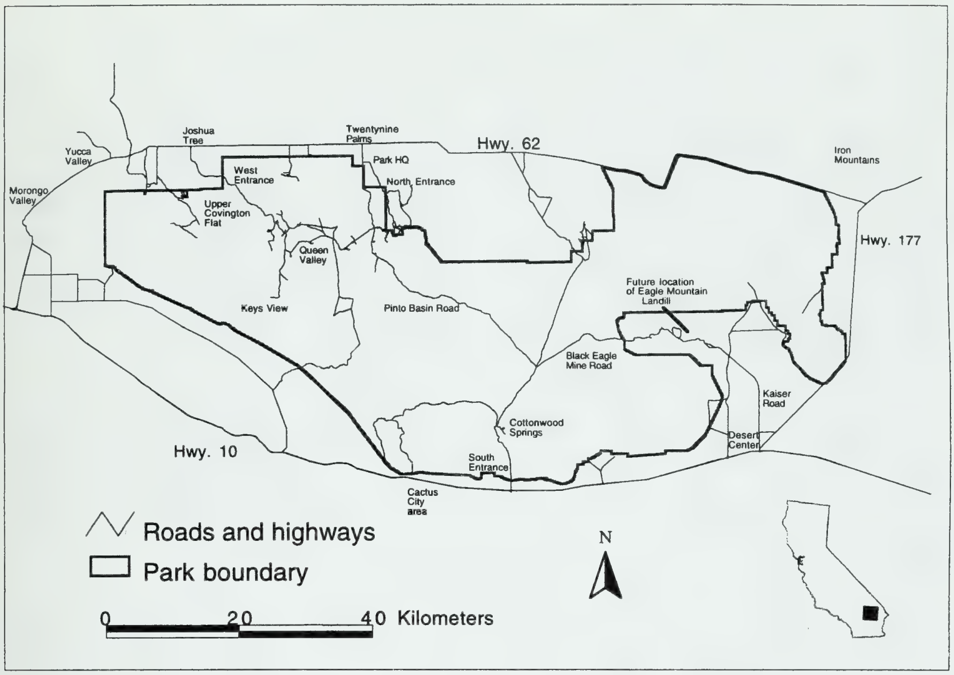
Joshua Tree
Twentynine Palms
Hwy. 62
Iron Mountains
Yucca Valley
West Entrance
Park HQ
North Entrance
Morongo Valley
Upper Covington Flat
Queen Valley
Hwy. 177
Future location of Eagle Mountain Landfill
Keys View
Pinto Basin Road
Black Eagle Mine Road
Kaiser Road
Cottonwood Springs
Desert Center
Hwy. 10
South Entrance
Cactus City area
Roads and highways
Park boundary
N
0 20 40 Kilometers

Fig. 1. Joshua Tree National Park and immediate surroundings.

mentation of a proposed large solid waste landfill in southeastern California adjacent to Joshua Tree National Park (JTNP) is considered to be a factor that could promote the establishment of additional populations of Common Ravens in the region, and/or increases in existing populations, which could further threaten the Desert Tortoise (Fig. 1). The proposed landfill, Eagle Mountain Landfill (EML), is currently in litigation. Should it be implemented as it was configured prior to legal proceedings, it is expected to receive up to 1,814 metric tons (1 metric ton=1000 kg) of garbage per day.

Resource managers at JTNP asked us to obtain and review information on the abundance and distribution of Common Ravens in and near the park as baseline information to be used in evaluating whether raven populations increase should EML be implemented (Boarman and Coe 2000a, 2000b). We located and evaluated both contemporary and historic data to assess what was known about Common Raven abundance and distribution.

Joshua Tree National Park consists of 794,000 hectares of Mojave Desert and Sonoran (Colorado) Desert plant communities. Areas that currently comprise JTNP were established as a National Monument in 1936. Through the California Desert Protection Act of 1994, the monument increased by 94,670 hectares and acquired National Park status. We refer to observations that were made within either the monument or park as having occurred in JTNP.

Methods

We searched for published and unpublished sources of information describing Common Raven abundance and distribution in and near JTNP. We obtained unpublished data such as field notes, species lists, and reports with the assistance of JTNP staff within the Resources Management and Interpretation Divisions. We also contacted JTNP volunteers and local experts, who held first-hand knowledge of ravens at the park, and obtained additional field notes from them. We acquired unpublished Breeding Bird Atlas (BBA) data for the two counties where JTNP is located (San Bernardino and Riverside Counties). We also contacted museums (California Academy of Sciences [CAS], Los Angeles County Museum of Natural History [LACMNH], San Bernardino County Museum [SBCM], San Diego Natural History Museum [SDNHM], Museum of Vertebrate Zoology [MVZ], and Western Foundation of Vertebrate Zoology [WFVZ]) for locations and dates of skins and eggs that had been collected in the region.

Results and Discussion

We located more than 13 sources of information pertaining to the occurrence of Common Ravens in JTNP and its vicinity, most of which pertained to the past 50 years (Table 1). The majority of data were unpublished records and pertained to observations within JTNP, although some included observations outside the park's boundaries.

Prehistoric information

Evidence from the fossil record indicates that Common Ravens were present in California deserts in prehistoric times. The species is known from Late Quaternary period deposits in San Bernardino County (Jefferson 1991). These include deposits that date back 100,000 to 4,000,000 years before present (BP) from the Mitchell Caverns located in the Providence Mountains (approximately 98 km northeast of JTNP). Raven fossils, whose age was estimated using radiometric dating to be approximately 12,500 years BP, are also known from Schuiling Cave in the Newberry Mountains (approximately 85 km northwest of JTNP; Jefferson 1991).

Historical (pre-1940) observations

Historical observations of Common Ravens in and near JTNP, and in southern California in general, helped us to estimate their densities prior to contemporary levels of human occupancy. Scant information is available about the abundance of the species in and adjacent to JTNP at the turn of the twentieth century. One of the earliest sources was the Death Valley Expedition of 1891 (Fisher 1893). Common Ravens were seen in Death Valley by every party that visited there between early January and late June. They were also seen in the Mojave Desert (location not provided) in early January, and in the Antelope Valley in June. Little information on the abundance of the species can be gleaned from this account. However, an observation of a minimum of 40 individuals foraging on grasshoppers in the Antelope Valley in June indicates that relatively large groups occurred at least occasionally. The report also stated that Common Ravens were believed to breed in the desert ranges of southern California and Nevada.

Van Rossem (1911) observed Common Ravens "about every day usually in pairs" in the winter of 1910/1911 in the Salton Sea region (Colorado Desert); the northern portion of the Salton Sea lies approximately 19 km from the southern border of JTNP. The species may have been more common to the north of the

Table 1. Sources of data obtained containing Common Raven occurrence in and near Joshua Tree National Park.

Source	Observers/Authors	Date	Description
1. Charles Adams' Bird Check list for Joshua Tree National Monument	C. Adams	1955–1956	Recorded species and numbers of birds observed at multiple locations
2. Joshua Tree National Park Natural History Field Observation Cards	Park visitors and staff	1959–1994	Observers recorded incidental sightings
3. National Audubon Society Christmas Bird Counts	Volunteers	Joshua Tree National Monument Count: 1969–present	Once each winter groups of observers count birds in a 24.2 km/15-mile diameter circle in an approximately 12-hour period
	Volunteers	Morongo Valley Count: 1982–present	
4. U.S.G.S. North American Breeding Bird Survey	Various observers	Joshua Tree route: 1970–1978, 1980, 1981, 1986–1988, 1991, 1994–2000	Count species and numbers of birds at stops every 0.8 km along three 39.4 km-long routes (50 stops per each route)
	Chet McGaugh	Cottonwood route: 1973, 1975, 1976, 1980, 1981, 1986–2000	
	Bill Truesdell	Cholla Garden route: 1995–2000	
5. Relative Abundance and distribution of Common Ravens	Knowles et al. 1989; Fauna-West Wildlife Consultants 1991	October 1988–March 1989	Recorded numbers of ravens along road transects that were driven twice per month
6. Personal field notes	Michael A. Patten	Spring 1987–Fall 1999	In both spring and fall of each year, counted all species of birds observed at five general locations: Morongo Valley, Twentynine Palms, Cactus City vicinity, Desert Center, Iron Mountain
7. JTNP Resource Management Division Common Raven Observations 1990–1992	Resource Management Division staff and volunteers	1990–1992	Observers recorded incidental sightings
8. Eagle Mountain Raven Transects	Camp et al. 1993	May–June 1992	Walked 32 transects
	A. Garry, C. Miller, J. Freilich, C. Collins, J. Grant, L. Johnson	January 1994	Walked four transects

Table 1. Continued..

Source	Observers/Authors	Date	Description
9. Eagle Mountain Landfill Biological Mitigation and Monitoring Program	RECON 1994	March 1993–February 1994	Recorded ravens at five point count locations and along three road transects
10. San Bernardino County and Riverside County Breeding Bird Atlases	Volunteers	Spring–Summer of 1987, 1988, 1989, 1991, 1992, 1994, 1996, 1997, 1998	Walked portions of a designated 5-km square and record species of birds and evaluate breeding status
11. Adopt-a-Raven Transects	Twentynine Palms Elementary School, Yucca Valley High School, Capistrano Valley High School	Spring 1997 through present	Road transect surveys; both the survey route length and the numbers of stops made along each route vary
12. Linear-right-of-way surveys	Knight and Kawashima 1993	May–June 1989	Numbers of Common Ravens and red-tailed hawks recorded on helicopter transects flown along linear right-of-ways
13. Museum records	Six museums in California	N/A	Museums provided records of specimens or eggs collected from Riverside and San Bernardino counties
14. Spring 1999 Observations	W. Boarman, S. Coe, W. Truesdell	April, May 1999	Incidental observations of ravens and raven nests

park, as Lamb (1912) reported it in the Mojave River Valley (102 km north of JTNP) in 1910 and 1911 as "common at all times everywhere, nesting on cliffs in the mountains." Gilman (1935) observed as many as 40 Common Ravens at one time at a wildlife feeding station at Death Valley National Park during observations made between October 1933 and May 1934 where he also reported a nest in a cliff. The earliest record from Joshua Tree National Park was an observation of a pair of Common Ravens in 1935 at Twentynine Palms Oasis, an area that lies within current park boundaries (Carter 1937). No indication of the abundance of the species was provided.

Few specimens from this time period and this region exist in museum collections. Therefore, little information about Common Raven distribution was gained beyond what we obtained from other sources; no information on abundance was acquired. The specimen taken closest to the park boundaries was 29 km southwest of the park border, collected in Mecca (Riverside County) in March 1908 (MVZ # 770). A specimen collected in "Walters, Imperial County" in January 1890 is considered to be from what is currently known as Mecca (SDNHM # 748; pers. comm. Philip Unitt). Two ravens were collected approximately 80 km northwest of JTNP in Victorville (San Bernardino County) in March 1907 (MVZ # 206) and in March 1914 (MVZ # 24573). All other specimens are from greater than 80 km from JTNP.

Distribution since 1940

There is an increasing amount of information about bird populations, including ravens, beginning in the mid-1900s. Grinnell and Miller (1944) cited portions of the Mojave Desert as being a major center of abundance of the species in California. However, Common Ravens do not appear on a species list for JTNP compiled in 1945 by Alden H. Miller that is on file at JTNP's Interpretation Division. Twenty years later, however, ravens were reported as a "sparse permanent resident" within JTNP (Miller and Stebbins 1964). What were populations like in the twenty-year period between 1945 and 1964?

Fortunately, detailed observations of Common Ravens within JTNP were collected in the mid-1950s by JTNP naturalist Charles Adams. He recorded species of birds at 76 locations within JTNP between January 1955 and September 1956, observing ravens in low numbers at 23 of the 76 locations. Most sightings were of 2–3 individuals per location per visit; the largest number at one location on a single visit was fourteen. It is possible that the absence of this species from Miller's 1945 bird list, in contrast to observations made by Adams roughly 10 years later, reflects an increase in size of the raven population in JTNP concomitant with an increase in human occupation and associated food resources in the area.

To gain insight into changes in distribution, we evaluated recent data for observations at locations where Adams never reported ravens. While Adams recorded the birds that were present at Cottonwood Springs 38 times, he did not record ravens as being present there (Fig. 1). Ravens have since been reported at Cottonwood Springs in two different data sets: (1) observations by visitors to the park reported on pre-printed index cards since the late 1950s (called Natural History Field Observation Cards); and (2) observations made by staff and volunteers of JTNP's Resource Management Division on an *ad hoc* basis between

1990 and 1992 both in and near JTNP. In the first data set, ravens were reported at Cottonwood Spring proper three times in 1978; in addition, one observation was made at a nearby picnic area in 1973, and two observations were made at a nearby residence in 1972 and 1973. In the second data set, the species was recorded once at the picnic area, and once on the road leading to the Spring. Similarly, Adams recorded no ravens at a location known as Queen Valley despite 32 visits. More recently, ravens have been reported in this area, on Natural History Field Observation Cards in 1978, and by the authors in 1999.

Both the Natural History Field Observation Cards and the JTNP's Resource Management Division observations support the hypothesis of current widespread distribution of ravens within JTNP. The former data set contains sightings of ravens at 29 locations, the latter contains 57 sightings at locations within and adjacent to the JTNP. Miller and Stebbins (1964) also reported Common Ravens as frequent scavengers along highways in the Coachella Valley in the Colorado Desert, which abuts JTNP's southern edge.

Breeding Bird Atlases are organized by volunteers and birding organizations in many regions throughout the United States to determine the breeding range of nesting species. In San Bernardino and Riverside Counties, BBA volunteers surveyed atlas "blocks" measuring 5 km square. This project confirms that Common Ravens bred in JTNP in 1987, 1992, and 1994. Ravens were designated as "probable" breeders in three blocks total (in 1987, 1988, and 1991), and as "possible" breeders in four blocks total (in 1987 and 1991). That the species is a current breeder at JTNP is not surprising given prior observations and the abundant suitable nesting habitat contained therein.

Densities in the Region

Virtually no information regarding densities of ravens is available for prior to the mid-1900s. The earliest data of this kind are from Charles Adams' work (maximum numbers observed) and from Miller and Stebbins (1964) who reported the species as "surprisingly scarce" at JTNP compared to their widespread occurrence in the desert and near cliffs in the southwest.

We did obtain three sources of data on raven densities from the past 12 years. The first source consisted of vehicle transect surveys conducted along paved highways and improved dirt roads in four regions of the California deserts in 1988 and 1989 (Knowles et al. 1989, FaunaWest Wildlife Consultants 1991). Only one portion of one of the routes occurred within JTNP, but three were located in its vicinity. Landfills and sewage ponds were also surveyed, with three of the landfills occurring near JTNP. Surveys were conducted over four 6-month periods. An index of the number of ravens observed per 161 km was calculated because the number of kilometers surveyed for each route varied. The portion of the route located in JTNP, running from the South Entrance to the North Entrance, recorded <1.0 to 6.0 ravens per 161 km over the four survey periods. For each of the three routes in the vicinity of JTNP, the number of ravens per 161 km ranged from 0 to 5.0 for all four survey periods (Table 2). These values are small compared to observations from routes in other parts of the study area (including areas with greater human density), which ranged from one to 49 ravens per 161 km.

Numbers of ravens at landfills ranged from 0 to 210 (Table 3) and tended to correspond positively with the numbers observed on road transects in their prox-

Table 2. Summary of Common Ravens observed on three road transects in the vicinity of JTNP (Knowles et al. 1989, FaunaWest Wildlife Consultants 1991).

Route	No. ravens observed	No. km traveled	No. observed per 161 km
SC-1			
Fall 1988	10	2309	.70
Winter 1989	18	2516	1.2
Spring 1989	3	2541	<1
Summer 1989	0	2533	0
SC-2			
Fall 1988	71	2297	5.0
Winter 1989	56	1911	4.7
Spring 1989	44	2309	3
Summer 1989	14	2127	1
FC-2			
Fall 1988	48	2202	3.5
Winter 1989	52	2178	3.8
Spring 1989	32	2217	2
Summer 1989	25	2212	2

imity. Landfills supported the largest concentrations of ravens in all four regions surveyed. Knowles et al. (1989) concluded that raven numbers observed at landfills were associated with the type, effectiveness, and frequency of waste burial and not with the size of the landfill or the amount of garbage present. They also concluded that ravens were more common in the Mojave Desert than the Colorado Desert, that their distribution tended to be clumped on certain road segments rather than being more or less evenly distributed, and that densities were highest near areas populated by humans (Knowles et al. 1989).

Surveys conducted in the immediate vicinity of the proposed Eagle Mountain Landfill provided even more recent information about raven densities (RECON 1994). Surveys were conducted in 1993 and 1994 on a monthly basis and included both hour-long counts made at single locations and vehicle transects along three routes (Table 4). The largest numbers of ravens observed at a point count location was at an existing small-scale landfill approximately 8 km from the proposed EML (range 5–40 individuals). The number observed on the three vehicle tran-

Table 3. Common Ravens observed at landfills in vicinity of Joshua Tree National Park (Knowles et al. 1989, FaunaWest Wildlife Consultants 1989).

	Total ravens observed on 12 twice-monthly visits					
Landfill	Fall 1988	Winter 1989	TOTAL	Spring 1989	Summer 1989	TOTAL
Landers	131	63	194	210	107	317
Amboy	1	0	1	2	0	2
Essex	40	31	71	2	0	2
Twenty-nine Palms	130	90	220	152	116	268
Desert Center	136	89	225	62	17	79
Indio	64	59	123	31	54	85

Table 4. Common Ravens observed on surveys for the Eagle Mountain Landfill Biological Mitigation and Monitoring Program (RECON 1994).

Location	Average no. ravens observed	Range of no. ravens observed	No. ravens observed per 1.61 km[1]
Point Stations			
Desert Center Dump	20	5–40	—
Kaiser Townsite	1	0–4	—
Eagle Mountain Mine	1	0–7	—
Tower[2]	0	0–4	—
Joshua Tree[3]	1	0–3	—
Vehicle Transects			
Eagle Mtn. Road (from I-10 to Metropolitan Water District pumping station; 11.3 km)	1	0–10	0.17
Kaiser Road (from Desert Center to Eagle Mountain Mine; 16.1 km)	2	0–10	0.15
Interstate 10 (from Chiriaco Summit to Desert Center Road; 31.4 km)	2	0–7	0.01

[1] (Route length) × (12 surveys).

[2] A tower located between Eagle Mountain Mine and Joshua Tree National Park.

[3] Overlooking Joshua Tree National Park from unspecified location.

sects was one, 15, and 17 ravens per 161 km, making the density on the last two routes notably higher than those observed by Knowles et al. (1989) and FaunaWest Wildlife Consultants (1991).

Knight and Kawashima (1993) surveyed linear right-of-ways by helicopter in May and June of 1989. Their coverage of 45,000 square km of Mojave Desert in San Bernardino County showed that ravens were more numerous on transects near powerlines and highways than in control areas. Also, raven nests were significantly more abundant along powerlines than along either highways or control areas. On the eight transects located in or near JTNP, only one raven was observed.

Raven Abundance In and Near JTNP

For monitoring changes in raven abundance over time, we considered standardized vehicle transects to be one of the best methods. Two such data sets exist: the U.S.G.S. North American Breeding Bird Survey (BBS), and a program coordinated by JTNP called Adopt-a-Raven Transects. The BBS has a vehicle route length of 39.4 km. At 0.8 km intervals counts are made of all birds heard and seen for a 3-minute period within a 0.4 km radius. Three BBS routes occur entirely or partially within the park. The "Joshua Tree" route (#14131) has been surveyed for 22 years since 1970, the "Cottonwood" route (#14088) for 20 years since 1973, and the "Cholla Garden" route (#14907) for six consecutive years beginning in 1995. The number of ravens recorded on the "Joshua Tree" route has increased over time (Fig. 2). For example, before 1989, numbers of ravens observed ranged between zero and nine. Since 1991, numbers observed have increased to between 10 and 32 per survey. This route starts in the northwest portion of JTNP and runs north through the town of Joshua Tree. We consider it likely that these data reflect actual increases in numbers of ravens given the stan-

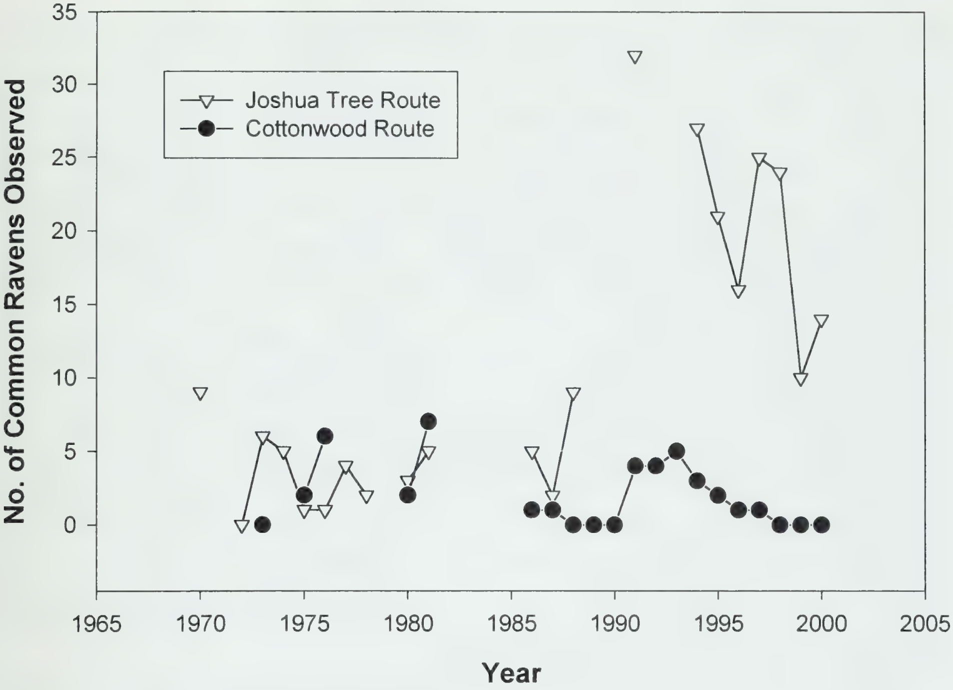

Fig. 2. Common Ravens observed on the "Joshua Tree" BBS Route between 1970 and 2000, and on the "Cottonwood" BBS Route between 1973 and 1997.

dardized survey methods. The increases in numbers observed may be correlated with the fact that the route is adjacent to, and travels through, the town of Joshua Tree, which has increased in human population size in the last 30 years; between 1970 and 1990, Joshua Tree's population more than tripled from 1,211 to 3,898 persons (California State Department of Finance 2000).

A second BBS route ("Cottonwood") runs from the park's south entrance to approximately its center. Relatively few ravens have been observed on this route (range 0–7) despite its having been surveyed in 20 different years, and in contrast to the "Joshua Tree" route, the small numbers have decreased since the early 1990's (Fig. 2). On the "Cholla Garden" route, which runs roughly east-west in the central portion of the park, the number of ravens observed has ranged from seven in 1996 to 21 in 1995; no increase has been detected.

BBS surveys occur strictly along paved roads, and because ravens tend to be attracted to roads (Knight and Kawashima 1993, Boarman and Heinrich 1999), BBS routes potentially overestimate the abundance of ravens in an area. Furthermore, the results of surveys like the BBS that are performed only once each year should be interpreted conservatively. Despite these caveats, increases in the numbers of ravens in the 1990's on the "Joshua Tree" route well above numbers from the 1970's and 1980's likely reflect actual increases in raven density in this area.

Like the BBS, the Adopt-a-Raven Transects were vehicular surveys. Counts were made at roughly 0.8 km intervals on five different routes in JTNP and one adjacent to it, ranging from twice to 35 times each. The route lengths are shorter than for the BBS surveys (ranging between 6.4 and 20.1 km), but cover both paved and unpaved roads. Most were repeated several times each year (Table 5). Because observers occasionally deviated from the established protocol and varied the distance between count locations, we calculated the average number of ravens per stop rather than the average number per kilometer. Of the three routes surveyed more than three times each, the two routes in the northeastern portion of JTNP resulted in more raven observations per point surveyed than did the route adjacent to the EML site. These differences could reflect a positive correlation between raven densities and human density. They may instead, or additionally, reflect a lower number of ravens in the Colorado Desert portion of JTNP due to habitat preferences.

The results of a relatively recent survey of undeveloped areas of the park supports the idea that raven densities in roadless regions in JTNP are much lower than in areas containing roads. Camp et al. (1993) surveyed for ravens in unpopulated areas adjacent to the proposed EML. Thirty-two transects totaling 283 km were walked in a 4-week period in 1992 in a largely roadless area. For each transect, the number of ravens observed per kilometer was calculated, and then averaged to obtain the number of ravens per 100 km. Only eight ravens were observed on the 32 transects surveyed. All observations were of single birds. The density was estimated to be 4.6 per 100 km ($SD = 9.78$), much lower than the mean of 36.5 ravens per 100 km estimated by Knight and Kawashima (1993) along paved highways in the Mojave Desert.

National Audubon Society Christmas Bird Count (CBC) data have been collected at Joshua Tree National Park once each winter since 1969 and at a second site immediately west of JTNP (Morongo Valley) since 1981. We interpreted these data cautiously because CBC methods are not well standardized compared to other sources of information (Bock and Root 1981). A CBC involves a group of observers counting the number of individuals of all species within a 24-km diameter circle in a 24-hour period, although little time is spent surveying in non-daylight hours. The participants typically divide themselves into small groups and each group covers different, non-overlapping locations in the 24-km area. A master list is compiled on which each group reports the total number of each species observed. We calculated the number of ravens observed per party-hour (the number ravens divided by the number of "party-hours") in an effort to partially reduce variation in CBC data resulting from the fact that the numbers of observers participating in the counts tends to vary among years. There was no way that we could control for differences in amount of time spent surveying different areas within the count circle, or for variation in weather. The number of ravens per party hour for both the Joshua Tree National Monument CBC and the Morongo Valley CBC showed statistically significant increases over their respective 30-year and 18-year histories (Fig. 3, Fig. 4; Joshua Tree: $r_s = 0.705$, $p < 0.0005$; Morongo Valley: $r_s = 0.834$, $p < 0.0005$).

We also analyzed unpublished observations of ravens by Michael A. Patten, a locally-based professional biologist with expertise in ornithology. Patten recorded birds between 1987 and 1999 at five areas near JTNP: Morongo Valley, Twentynine Palms, Iron Mountain (approximately 12.9 km northeast of the northeast border of the park), Cactus City (12.9 km west of the park's south entrance), and Desert Center (Fig. 1). Each year, surveys were made in spring and fall of some or all of the five areas. We calculated the average number of ravens observed at

Table 5. Common Ravens observed on Adopt-a-Raven Transect surveys.

Transect Name	Period surveyed	No. of times surveyed	Route length	Average no. observed each visit	Average no. observed per point (stop) surveyed
Inside of JTNP					
Queen Mountain Road	3/19/97–4/16/97	3	10–11.6 km	5 (range 0–3)	0.71
Covington Flats	4/30/97–5/30/98	17	6.4–7.2 km	2.1 (range 0–5)	0.22
Keys View Road	10/15/97–6/3/98	16	8.1–12.9 km	4.9 (range 0–39)	0.45
Black Eagle Mine Road	4/19/97–5/99, 7/99–10/99 (on-going)	35	9.7–17.0 km	0.3 (range 0–2)	0.5
“Geology Tour”	3/15/97, 3/16/97	2	12.1–20.1 km	5.5 (range 3–8)	0.82
Outside of JTNP					
Kaiser Road (Desert Center)	5/14/97–10/19/97	2	12.1–19.3 km	6 (range 4–10)	0.75

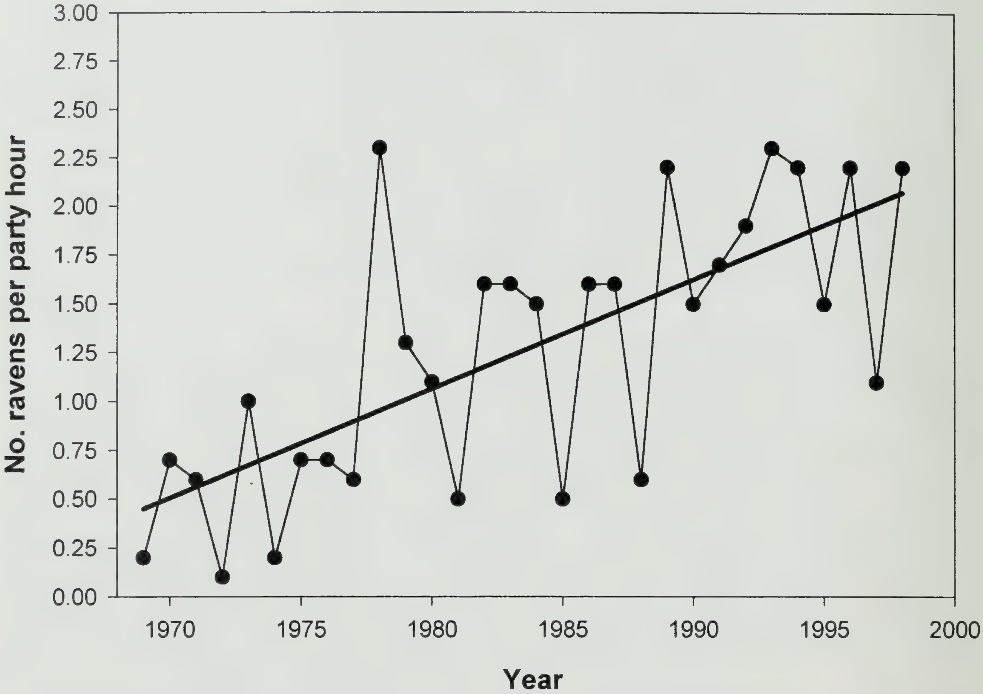

Fig. 3. Common Ravens observed on the Joshua Tree Christmas Bird Counts ($r_s = 0.705$, $p < 0.0005$).

each of the five survey regions for spring and fall observations separately. A statistically significant increase in raven numbers was observed for fall surveys (Spearman rank correlation, $r_s = 0.624$, $p < 0.05$) but not for spring surveys (Spearman rank correlation, $r_s = -0.036$, $p > 0.90$).

A Breeding Bird Census (BBC) conducted in Morongo Valley at the Big Morongo Canyon Reserve annually between 1977 and 1995 produced ravens in only a few years. The area was censused 8–9 times each spring to determine the numbers of species breeding and/or otherwise utilizing the area. Ravens were listed as a "visitor" in 1983, 1984, 1985, 1986, 1988, and 1994, indicating that individuals were observed in the census area but were not observed breeding when observed. The numbers of ravens that were observed were not provided. The census area was 15.38 hectares in size and consisted of marsh, riparian woodland and mesquite thickets (95% of total area), and small areas of brush. The habitat characteristics may have influenced the infrequency of observations since ravens tend not to utilize woodland and thicket habitat in deserts of southern California.

Conclusions

None of the data sets we obtained was a comprehensive assessment of Common Raven distribution or density in JTNP for any time period. Furthermore, the majority of the sources consisted of data that were collected without the use of a standardized methodology, and/or were collected over a short time period. Despite

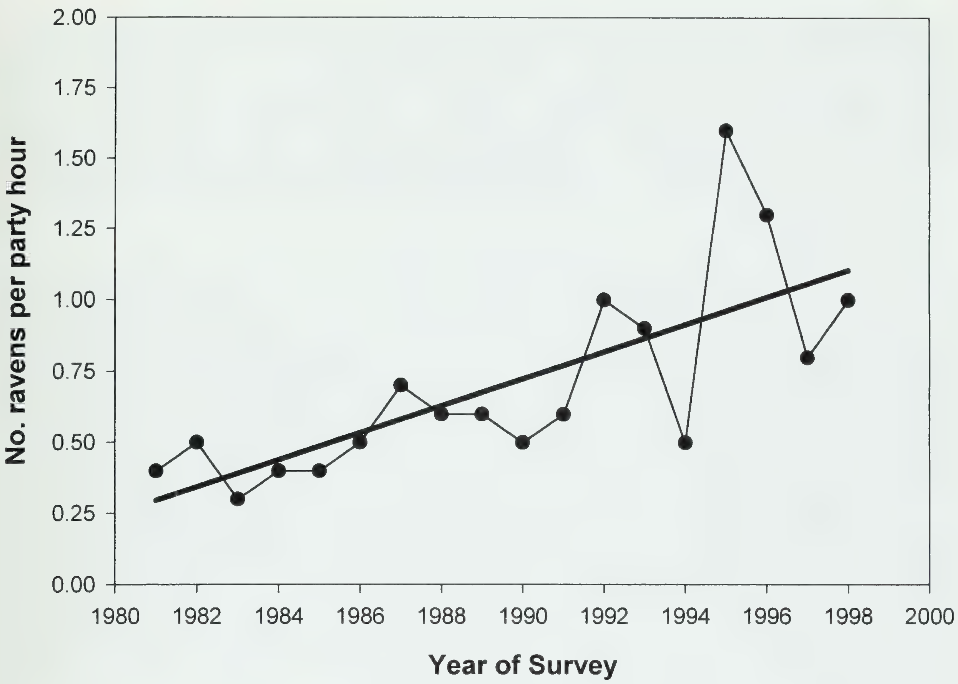

Fig. 4. Common Ravens observed on the Morongo Valley Christmas Bird Counts ($r_s = 0.834$, $p < 0.0005$).

these limitations, we gained enough historical and temporal information about ravens to reach the following qualitative conclusions:

1. Ravens were present in the southern California desert (east Mojave) thousands of years ago.

Fossil evidence shows that ravens occupied the east Mojave Desert tens of thousands of years ago. Observations of live individuals in the Mojave and Colorado Deserts date back as far as the late 1800s and early 1900s. These data support the contention that Common Ravens are a native component of the avifauna in southern California deserts.

2. Ravens have been documented in JTNP for more than 50 years.

The first documented observation of ravens in JTNP was in 1935 (Carter 1937), later supplemented extensively by observations from Charles Adams in the mid-1950s. Breeding in the region was suggested by observations during the Death Valley Expedition of 1891 (Fisher 1893). Breeding Bird Atlas (BBA) data confirmed that ravens continue to breed in JTNP. In limited surveys in 1999, we located eight nests in the park (Boarman and Coe 2000a).

3. Raven densities may be higher in the Mojave Desert than the Colorado Desert.

JTNP consists of two types of desert: Mojave and Colorado. During the Adopt-a-Raven Transects surveys, more ravens were observed along routes in the northern portions of the park (Mojave) than in the central and southeast portions (Colorado). These observations are in agreement with those of Knowles et al. (1989) and FaunaWest Wildlife Consultants (1991) that indicated ravens were more common in the Mojave than in the Colorado Desert based on vehicle transect surveys. Patten et al. (in press) also reports Common Ravens as being uncommon in the Salton Sink portion of the Colorado Desert and fewer in number than in the Mojave Desert.

4. The numbers of ravens observed in JTNP has increased over the last 50 years.

The absence of Common Raven from Miller's 1945 bird list for JTNP, compared to the regular observations by Charles Adams in the mid-1950s may suggest a period when populations began visibly expanding. BBS data suggest that raven numbers have increased on the "Joshua Tree" route. Although the "Cottonwood" BBS route has not shown a corresponding increase, this route covers Colorado Desert habitat where ravens may be less abundant (see Conclusion 3, above).

CBC data also indicate an increase in raven numbers. The number of ravens per party hour for both the Joshua Tree National Monument CBC and the Morongo Valley CBC increased over their respective histories. Increases in ravens in JTNP are consistent with the results of an analysis of BBS data for the Sonoran and Mojave Deserts by Boarman and Berry (1995) showing that raven populations increased 450–1000% over a recent 24-year period.

5. The distribution of ravens in JTNP has expanded in the last 50 years.

Common Ravens are now known to occur in locations where Charles Adams never reported them in the mid-1950s (e.g., Cottonwood Springs and Queen Valley).

6. Raven densities are lower in regions without roads.

Surveys by Camp et al. (1993) in unpopulated areas adjacent to the proposed Eagle Mountain Landfill resulted in a density estimate of 4.63 per 100 km which was lower than the mean of 36.5 ravens per 100 km estimated by Knight and Kawashima (1993) along paved highways in the Mojave Desert.

7. Landfills in the Mojave Desert are some of the largest concentration areas for ravens.

This observation was made by Knowles et al. (1989) and FaunaWest Wildlife Consultants (1991) who surveyed landfills, sewage ponds and roads. In addition, multi-year surveys in the western Mojave Desert at Fort Irwin (approximately 130 km north of the park), and in and around Edwards Air Force Base (approximately 130 km north-east of the Park), yielded significantly more ravens at landfills than at sewage ponds, golf courses, city streets, and undeveloped desert locations (Boarman et al. 1995).

Observations of ravens in Joshua Tree National Park have increased and their populations are presumably expanding. Because of their use of landfills for food, raven numbers in JTNP will likely increase following implementation of Eagle Mountain Landfill. A program to monitor raven populations in and around JTNP should be implemented to evaluate expected changes and should cover areas where ravens have occurred regularly over the past 50 years, as well as where they have rarely occurred. Road-based surveys coupled with point counts at specific attraction sites, following standardized protocols and occurring throughout the year, would provide the most reliable results. Following radio- and wing-tagged ravens from the landfill would yield important data on the direct influence the landfill has on the JTNP raven population.

Acknowledgements

We would like to thank the numerous persons who provided data and information for this manuscript, including William Truesdell, Ray Panici, Michael A. Patten, Chet McGaugh, Richard Camp, and JTNP staff Gillian Bowser and Joseph Zarki. Several museums provided information from their collections including California Academy of Sciences (Douglas Long), Los Angeles County Museum of Natural History (Kimball Garrett), San Bernardino County Museum (Robert McKernan), San Diego Natural History Museum (Philip Unitt), Museum of Vertebrate Zoology, and Western Foundation of Vertebrate Zoology (Rene Corado). Comments and suggestions were provided by Michael A. Patten, Richard Camp, and Chet McGaugh. We also thank Gillian Bowser, Hank McCutchen, and Ernie Quintana for their support of the project from its inception.

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Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus.* J. Mamm., 54:452–458.

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SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

Volume 101 **Supplement to Number 2**

ABSTRACTS OF PAPERS

2002 Annual Meeting
Claremont McKenna College
Claremont, California

June 7–8, 2002

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Acknowlegements

The Southern California Academy of Sciences wishes to acknowlege the following organizations and people for their support of the 2002 Annual Meeting

Dr. Robert Phelan, U.C. Irvine
The Port of Los Angeles
Sea Grant Program, University of Southern California

STUDENT AWARD WINNERS AT 2002 ANNUAL MEETING

At the 2002 Annual Meeting, held June 7–8 at Claremont McKenna College, Claremont, California, the following student papers and posters won awards.

Awarded by the American Institute of Fishery Research Biologists

Best Paper
Daniel Cartamil and C. Lowe. California State University, Long Beach
DIEL MOVEMENT PATTERNS OF THE OCEAN SUNFISH, MOLA MOLA: A PRELIMINARY REPORT

1st Runner Up
Yannis P. Papastamatiou and Christopher G. Lowe, California State University Long Beach
***IN SITU* MONITORING OF GASTRIC pH CHANGES ASSOCIATED WITH FEEDING IN LEOPARD SHARKS**

2nd Runner up
Matthew T. Craig, P. A. Hastings, and P. K. Dayton. Scripps Institution of Oceanography
THE NEARSHORE FISH ASSEMBLAGE OF THE SAN DIEGO/LA JOLLA ECOLOGICAL RESERVE

Honorable Mention
Ronit Lavie and C. Hogue, California State University Northridge
PARASITE-MEDIATED SEXUAL SELECTION OF GREEN SWORDTAILS, *XIPHOPHORUS HELLERI*

Awarded by the Southern California Academy of Sciences

Best Poster
Ronit Lavie and C. Hogue, California State University Northridge
PARASITE-MEDIATED SEXUAL SELECTION OF GREEN SWORDTAILS, *XIPHOPHORUS HELLERI*

Best Paper, Physiology
R. A. Cohen and P. Fong, University of California, Los Angeles
PHYSIOLOGICAL RESPONSES TO VARIATIONS IN SALINITY AND NUTRIENTS BY THE BLOOM-FORMING MACROALGA *ENTEROMORPHA INTESTINALIS*: IMPLICATIONS FOR USE AS A BIOINDICATOR OF FRESHWATER AND NUTRIENT INFLUX TO ESTUARINE AND COASTAL AREAS

Best Paper, Ecology and Evolution
K.E. Drewe and M.H. Horn. California State University, Fullerton
ONTOGENETIC RESPONSES TO TERRESTRIAL DIETS IN A NEOTROPICAL FISH: GUT MORPHOLOGY AND DIGESTIVE ENZYME ACTIVITY IN *BRYCON GUATEMALENSIS* (CHARACIDAE)

Southern California Academy of Sciences 2002 Session Schedule

Friday June 7
Location: Pickford Auditorium

Symposium: Large Scale Marine Monitoring in the Southern California Bight

Chair: Stephen B. Weisberg, Southern California Coastal Water Research Project.

1. 8:40 **SEDIMENT TOXICITY IN THE SOUTHERN CALIFORNIA BIGHT: 1998 REGIONAL MONITORING.** S. M. Bay*, Southern California Coastal Water Research Project, Westminster, CA, D. Lapota, Space and Naval Warfare Systems Center, San Diego, CA, J. Anderson, Columbia Analytical Services, Vista, CA, T. Mikel, Aquatic Bioassay and Consulting Laboratories, Inc., Ventura, CA, J. Armstrong, Orange County Sanitation District, Fountain Valley, CA.
2. 9:00 **IDENTIFICATION OF CONTAMINATED SEDIMENTS IN THE SOUTHERN CALIFORNIA BIGHT USING A BIOMARKER ASSAY (RGS: EPA METHOD 4425).** J. W. Anderson, J. M. Jones, D. McCoy, Columbia Analytical Services and E. Zeng, J. A. Noblet, So. Calif. Coastal Water Research Project (SCCWRP).
3. 9:20 **THE SPATIAL DISTRIBUTION OF SEDIMENT CONTAMINATION IN THE SOUTHERN CALIFORNIA BIGHT.** J. A. Noblet and Shelly L. Moore, Southern California Coastal Water Research Project, Westminster, CA, 92683-5218
4. 9:40 **A HISTORICAL VIEW OF MARINE SEDIMENT CONTAMINATION SURVEYS IN SOUTHERN CALIFORNIA FROM 1977 TO 1998.** R. W. Gossett, CRG Marine Laboratories, Inc., Torrance, CA, 90501
5. 10:00 **MUSSEL MANIA; LONG-TERM CONTAMINANT TRENDS IN THE SOUTHERN CALIFORNIA BIGHT.** A. J. Mearns and T. P. O'Connor. National Oceanic and Atmospheric Administration, Seattle, WA and Silver Springs, MD.
6. 10:20 **A REVIEW OF THE KELP BEDS OF ORANGE AND SAN DIEGO COUNTIES AND THEIR RESPONSE TO EL NINOS AND LA NINAS FROM 1967 TO 2001**. M. D. Curtis[1] and W.J. North[2]. [1] **MBC Applied Environmental Sciences, Costa Mesa, CA. 92626 and** [2] Caltech Kerchoff Marine Laboratory, Newport Beach, CA.

10:40 Break

11:00 **Plenary Speaker: Walter Fitch, University of California, Irvine "Creation Science: an Oxymoron"**

12:00 Lunch

7. 1:20 **LARGE SCALE OCEANOGRAPHIC STUDIES OF THE CONTINENTAL SHELF OF THE SOUTHERN CALIFORNIA BIGHT; THE EXAMPLE OF BIGHT 98 AND FUTURE APPROACHES.** B. H. Jones, Department of Biological Sciences, University of Southern California, Los Angeles, CA 90089-0371.
8. 1:40 **A HALF CENTURY OF PHYSICAL AND BIOLOGICAL OCEANOGRAPHY IN THE SOUTHERN CALIFORNIA BIGHT WITH EMPHASIS ON FISH SPECIES TEMPERATURE AND ZOOPLANKTON.** P. E. Smith and H. G. Moser, Southwest Fisheries Science Center [NOAA/NMFS], 8604 La Jolla Shores Drive, La Jolla CA 92038.
9. 2:00 **ASSESSMENT OF DEMERSAL FISH AND INVERTEBRATE ASSEMBLAGES ON THE SOUTHERN CALIFORNIA SHELF IN 1998.** M. J. Allen[1], A. K. Groce[2], D. Diener[3], V. Raco-Rands[1], Christina Thomas[4], and Yvette Ralph[4]. [1]Southern California Coastal Water Research Project, Westminster, CA 92683; [2]City of San Diego, Metropolitan Wastewater Department, San Diego, CA; [3]MEC Analytical Systems, Inc., Carlsbad, CA 92008; [4]Orange County Sanitation District, Fountain Valley, CA 92008.
10. 2:20 **PAH EXPOSURE AND DNA DAMAGE IN FLATFISH FROM SOUTHERN CALIFORNIA BAYS AND HARBORS AND CHANNEL ISLANDS.** J. S. Brown, Southern California Coastal Water Research Project, Westminster, CA, 92683, and S.A. Steinert, Computer Science Corporation, San Diego, CA, 92110
11. 2:40 **PORTS OF LONG BEACH AND LOS ANGELES BIOLOGICAL MONITORING OF SAN PEDRO BAY.** K. Green, MEC Analytical Systems, Inc. 2433 Impala Drive, Carlsbad, CA 92008

3:00 Break

12. 3:20 **SOFT-BOTTOM BENTHIC INVERTEBRATE ASSEMBLAGES OF THE SOUTHERN CALIFORNIA BIGHT.** J. A. Ranasinghe[1], D.E. Montagne[2], D.B. Cadien[2], R.G. Velarde[3], T. K. Mikel[4], R.W. Smith[5], S.B. Weisberg[1] and A. Dalkey[6]. [1]Southern California Coastal Water Research Project, 7171 Fenwick Lane, Westminster, CA, 92683. [2]County Sanitation District of Los Angeles County, P.O. Box 4998, Whittier, CA, 90607. [3]City of San Diego, 4918 N. Harbor Dr., Ste 101, San Diego, CA, 92106. [4]Aquatic Bioassay and Consulting Laboratories, Inc., 29 North Olive Street, Ventura, CA, 93001. [5]P.O. Box 1537, Ojai, CA 93024-1537. [6]City of Los Angeles, Environmental Monitoring Division, 12000 Vista del Mar, Playa del Rey, CA 90293.

13. 3:40 **DIVERSITY-ABUNDANCE RELATIONSHIPS IN BENTHIC HABITATS OF THE SOUTHERN CALIFORNIA BIGHT** Tim Mikel. Aquatic Bioassay and Consulting Laboratories, Inc., 29 North Olive Street, Ventura, CA, 93001

14. 4:00 **HOW IMPORTANT ARE NONINDIGENOUS SPECIES TO THE BENTHOS OF SOUTHERN CALIFORNIA EMBAYMENTS?** R. G. Velarde, City of San Diego, 4918 N. Harbor Dr., Ste 101, San Diego, CA, 92106, J.A. Ranasinghe, Southern California Coastal Water Research Project, 7171 Fenwick Lane, Westminster, CA, 92683 and D.B. Cadien, County Sanitation District of Los Angeles County, P.O. Box 4998, Whittier, CA, 90607.

15. 4:20 **MARINE: THE MULTI-AGENCY ROCKY INTERTIDAL NETWORK.** M. E. Dunaway, Minerals Management Service, Camarillo 93010.

16. 4:40 **POST-RESTORATION LONG-TERM MONITORING FOR THE BATIQUITOS LAGOON ENHANCEMENT PROJECT.** K. Merkel[1], H. D. Henderson[1], R. A. Woodfield[1], and M. Carpenter[2]. [1]Merkel & Associates, Inc., San Diego, CA 92123. [2]KTU+A, San Diego, CA 92103

Friday June 7
Location: Bauer Forum

Contributed Papers

Chairs: Ralph Appy, Port of Los Angeles, Judith Lemus, Sea Grant Program, U.S.C., and John Dorsey, City of Los Angeles.

17. 8:40 **ATMOSPHERIC DEPOSITION OF TRACE METALS TO SANTA MONICA BAY.** K. Schiff, L. Tiefenthaler, Southern California Coastal Water Research Project, Westminster, CA, and K. Stolzenbach, R. Lu, R. Turco, S. Friedlander, University of California Los Angeles, Los Angeles, CA.

18. 9:00 **CHARACTERISTICS, FORMATION MECHANISMS AND CHEMICAL COMPOSITION OF ULTRAFINE PARTICLES IN VARIOUS LOCATIONS OF THE LOS ANGELES BASIN.** Constantinos Sioutas, Si Shen, Michael D. Geller, Chandan Misra and Seongheon Kim, University of Southern California, Department of Civil and Environmental Engineering, 3620 South Vermont Avenue, Los Angeles, CA 90089

19. 9:20 **AUTOTOMY: NOVEL PROTECTION FROM MERCURY TOXICITY IN AQUATIC OLIGOCHAETE WORMS.** Doris Vidal. Southern California Coastal Water Research Project. Toxicology Department. Westminster CA 92683-5218

20. 9:40 **EQUAL LOADS OF NUTRIENTS ADMINISTERED TO MACROALGAE VIA PULSES OF DIFFERENG FREQUENCY AND MAGNITUDE AFFECT GROWTH AND TISSUE NUTRIENTS OF ENTEROMORPHA INTESTINALIS AND ULVA EXPANSA.** **Krista Kamer**[1], Rachel L. Kennison[2], and Peggy Fong[2]. [1]Southern California Coastal Water Research Project, Westminster CA 92683. [2]University of California, Los Angeles, Department of Organismic Biology, Ecology and Evolution, Los Angeles CA 90095.

21. 10:00 **MORPHOLOGICAL VARIATION AND PATTERNS OF REPRODUCTION AND RECRUITMENT IN LOWER INTERTIDAL POPULATIONS OF THE KELP *EGREGIA MENZIESII* (TURNER) ARESCHOUG.** Henkel, Sarah K. and Murray, Steven N. Department of Biological Science, California State University, Fullerton, PO Box 6850, Fullerton, CA 92834-6850

22. 10:20 **HABITAT ASSOCIATIONS OF STEELHEAD TROUT IN A SMALL STREAM NEAR THE SOUTHERN EXTENT OF THEIR RANGE.** A. P. Spina. National Marine Fisheries Service, Southwest Region, Long Beach, CA 90802.

10:40 Break

11:00 **Plenary Speaker: Walter Fitch, University of California, Irvine "Creation Science: an Oxymoron"**

12:00 Lunch

23. 1:20 ***IN SITU* MONITORING OF GASTRIC pH CHANGES ASSOCIATED WITH FEEDING IN LEOPARD SHARKS.** Yannis P. Papastamatiou and Christopher G. Lowe, Department of Biological Sciences, California State University Long Beach, 1250 Bellflower Blvd., Long Beach CA 90840.

24. 1:40 **ONTOGENETIC RESPONSES TO TERRESTRIAL DIETS IN A NEOTROPICAL FISH: GUT MORPHOLOGY AND DIGESTIVE ENZYME ACTIVITY IN *BRYCON GUATEMALENSIS (*CHARACIDAE).** K.E. Drewe and M.H. Horn. California State University, Fullerton, Department of Biology, Fullerton, CA 92834

25. 2:00 **DIEL MOVEMENT PATTERNS OF THE OCEAN SUNFISH, MOLA MOLA: A PRELIMINARY REPORT.** D. Cartamil and C. Lowe. California State University, Long Beach, Department of Biological Sciences, Long Beach, California, 90840.

26. 2:20 **INCIDENCE OF *SALMONELLA* IN FREE RANGING IGUANID LIZARDS OF SOUTHERN CALIFORNIA.** Jeffery Burkhart, Ron Fauntleroy, and Kelly Spencer, Department of Biology, University of La Verne, La Verne, CA. 91750

27. 2:40 **OIL IMPACT ON GROWTH OF *SALICORNIA VIRGINIA* UNDER CONTROLLED TIDAL CONDITIONS.** C.Y. Chen, D.D. Portugal, T. Zuniga and A.H.B.M. Wijte. California State University, Long Beach, Department of Biology, Long Beach, CA, 90840.

3:00 Break

28. 3:20 **EXAMINATION OF RECRUITMENT PATTERNS IN KELP BASS, *PARALABRA CLATHRATUS* BY THE ANALYSIS OF MITOCHONDRIAL DNA CONTROL REGION SEQUENCES.** Christina W. Luzier and Raymond R. Wilson, Jr., California State University, Long Beach, Department of Biological Sciences, Long Beach, CA 90840

29. 3:40 **BEHAVIORAL RESPONSES OF SCALLOPED HAMMERHEAD SHARKS, *SPHYRNA LEWINI*, AND LEOPARD SHARKS, *TRIAKIS SEMIFASCIATA*, TO PULSED, DIRECT CURRENT ELECTRICAL FIELDS.** M.M. Marcotte. California State University, Long Beach, Department of Biological Sciences, Long Beach, CA, 90840.

31. 4:00 **FISH SPECIES COMPOSITION FROM THE SEAFOOD MARKET OF ENSENADA, BAJA CALIFORNIA, MEXICO (2000–2001).** Hernandez-Hernandez, Alejandra y Jorge A. Rosales-Casian, Departamento de Ecología, Grupo de Ecología Pesquera Centro de Investigación Científica y Educación Superior de Ensenada (CICESE) Km 107 carretera Tijuana-Ensenada, Ensenada Baja California, México. U.S. Mailing: P.O. Box 434844, San Diego California 92143-4844 U.S.A.

Friday June 7 5–7 p.m.
Location: McKenna Auditorium

Poster Session: and Wine and Cheese Social

32. **POLYCHAETOUS ANNELID ASSEMBLAGES ASSOCIATED WITH SEDIMENTS NEAR SEVEN SHALLOW WASTEWATER OUTFALLS ALONG THE TIJUANA-ENSENADA COSTAL CORRIDOR IN NORTHERN BAJA CALIFORNIA, MEXICO.** V. Rodríguez-Villanueva[1], R. Martínez-Lara[2] and V. Macías-Zamora[1]. [1]I.I.O. Universidad Autónoma de Baja California. Km 107 Carretera Tijuana-Ensenada. Apartado Postal 453. Ensenada, B.C. México; [2]Marine Biology Laboratory, City of San Diego Ocean Monitoring Program. 4918 North Harbor Drive, Suite # 101, San Diego, CA 92106. U.S.A.

33. **POPULATION SYSTEMATICS OF THE CAROLINA ANOLE, *ANOLIS CAROLINENSIS* VOIGT (SQUAMATA: IGUANIA: POLYCHROTIDAE): GEOGRAPHIC VARIATION IN MORPHOLOGY.** W.C.H. Chun[1] and J.W. Archie[2]. [1]University of California, Department of Organismic Biology, Ecology, and Evolution, Los Angeles, CA, 90095; and [2]California State University, Department of Biological Sciences, Long Beach, CA, 90840.

34. **SALT TOLERANCE AND REMEDIATION POTENTIAL OF *SALIX LASIOLEPIS*: A NATIVE CALIFORNIA WILLOW.** A. Ferrus-Garcia, C.M Vadheim, J. Roberts. Department of Biology, CSU Dominguez Hills, Carson CA 90747

35. **NORTHERN ORANGE COUNTY FALL 2001 WEATHER SUMMARY** G.P. Hannes, California State University, Fullerton, Department of Geogrpahy, Fullerton, CA 92634.

36. **TROPHIC LEVELS AND HEAVY METAL CONCENTRATIONS OF TERNS AT TWO CALIFORNIA NESTING COLONIES.** M.H. Horn[1], A.Z. Mason[2], D.R. Smith[1], E.A. Logothetis[3] and C.T. Collins[2]. [1]Department of Biological Science, California State University, Fullerton, Fullerton, CA 92834 [2]Department of Biological Science, California State University, Long Beach, Long Beach, CA 90840, [3]1810 Perry Avenue, Wilmington, NC 28403.

37. ***ACANTHOCHONDRIA SP.* A, A NEW SPECIES OF PARASITIC COPEPOD POECILOSTOMATOIDA: CHONDRACANTHIDAE) ON THE CALIFORNIA HALIBUT, *PARALICHTHYS CALIFORNICUS*, FROM SANTA MONICA BAY, CALIFORNIA.** *Julianne Kalman.* Department of Organismic Biology, Ecology, and Evolution, University of California, Los Angeles (UCLA), Los Angeles, CA 90095-1606

38. **PARASITE-MEDIATED SEXUAL SELECTION OF GREEN SWORDTAILS, *XIPHOPHORUS HELLERI*.** R. Lavie and C. Hogue, California State University, Northridge, Department of Biology, Northridge, CA, 91330

39. **THE BENTHIC COMMUNITY OF SAN DIEGO BAY.** E.C. Nestler, D. Pasko, and T. D. Stebbins. Marine Biology Laboratory, City of San Diego Ocean Monitoring Program, 4918 N. Harbor Drive, Suite #101, San Diego, CA 92106, USA.

40. **PROBABLE LATERITE IN THE PALEOCENE LAS VIRGENES SANDSTONE, SOLSTICE CANYON, SANTA MONICA MOUNTAINS, CALIFORNIA.** G.R.Noriega, H.O. Hernandez, Dr. P. Ramirez, California State University Los Angeles, Department of Geological Sciences, Los Angeles, CA, 90032

41. **ASSESSMENT OF THE HEALTH OF KELP HABITATS ALONG THE NORTH COAST OF SANTA MONICA BAY.** B. Reed[1], P. Fong[2], and J.R. Smith[2]. [1]Santa Monica BayKeeper, [2]University of California, Los Angeles (Funded by the Santa Monica Bay Restoration Foundation).

42. **SOIL MICROBIAL ACTIVITY AND MYCORRHIZAL ASSOCIATION IN A SOUTHERN CALIFORNIAN SALT MARSH.** Matthew W. Vandersande and Dr. Richard F. Ambrose Environmental Science and Engineering Program, UCLA

43. **OCCURRENCE OF *Gyrodactylus perforatus* (MONOGENEA) ON ITS FISH HOST *Clevelandia ios* (Gobiidae) FROM BODEGA BAY AND TOMALES BAY, CALIFORNIA.** M. P. Walberg, E. Diamant, and K. Wong. University of California, Los Angeles, Department of Organismic Biology, Ecology, and Evolution, Los Angeles, CA, 90095.

100. **A COMPARISON OF THE VOCALIZATIONS OF TWO SPECIES OF FYLING FOXES IN THE SAMOAN ARCHIPELAGO.** Eiler, K; J. Newmark; B. Drummond; C. Stewart; and S. Banack, California State University, Department of Biological Science, Fullerton, CA. 92831.

Saturday June 8
Location: Bauer Forum

Symposium: Conservation Management

Chair: Brad Blood, Sapphos Environmental.

44. 9:00 **MANAGEMENT OF THE CALIFORNIA LEAST TERN BREEDING POPULATION.** Kathy Keane, Keane Biological Consulting, 5546 Parkcrest Street, Long Beach CA 90808 USA, *keanebio@cs.com*

45. 9:20 **CONSERVATION OF THE ENDANGERED SOUTHERN CALIFORNIA STEELHEAD IN THE VENTURA RIVER: AN UPDATE ON THE PROPOSED REMOVAL OF MATILIJA DAM.** Sabrina L. Drill. University of California Cooperative Extension, 2 Coral Circle, Monterey Park, CA 91755.

46. 9:40 **CONSERVATION DILEMMAS INVOLVING ENDANGERED SPECIES IN THREE SOUTHERN CALIFORNIA HABITATS; SAN MIGUEL ISLAND, BOLSA CHICA WETLANDS AND RIPARIAN WOODLANDS.** Daniel A. Guthrie, Claremont McKenna College, Claremont, Ca. 91711

47. 10:00 **THE IMPORTANCE OF MANAGEMENT OF THE NATIVE PARASITIC PLANT *CUSCUTA SALINA* IN SOUTHERN CALIFORNIA SALT MARSH HABITAT.** Christina Simokat, Department of Biology, California State University San Marcos, San Marcos, CA 92096.

48. 10:20 **AVIAN POPULATIONS IN DIMINISHING OPEN SPACE: A SURVEY OF THE BIRDS OF SIGNAL HILL, CA.** V. Anne Short, Department of Biological Sciences, California State University, Long Beach, California.

10:40 Break

11:00 **Plenary Speaker: Gregor Hodgson, U.C.L.A. on "John Q. Public Saves Coral Reefs." Pickford Auditorium**

12:00 Lunch

Symposium: Exotic Species

Chair: Dan Guthrie, Claremont Colleges

49. 1:40 **ARE SOUTHERN CALIFORNIA'S CHANGING COASTAL WATERS AND NEARSHORE BIOLOGICAL COMMUNITIES BECOMING MORE SUSCEPTIBLE TO INVASION BY EXOTIC SEAWEEDS?** S. N. Murray. Department of Biological Science, California State University, Fullerton, CA 92834-6850

50. 2:00 **WHAT IS NONINDIGENOUS AND IS IT ALL BAD?** J. N. Baskin and T. R. Haglund, California State Polytechnic University Pomona, Biological Sciences Department, Pomona, CA 91768.

51. 2:20 **THE MARINE INVADERS OF CALIFORNIA: LESSONS FROM SAN FRANCISCO AND SAN DIEGO.** Jeffrey A. Crooks. Tijuana River National Estuarine Research Reserve, Imperial Beach, CA. 91933

52. 2:40 **U.S. RESPONSE TO POTENTIAL ECOLOGICAL THREAT TO SOUTHERN CALIFORNIA ECOSYSTEMS BY THE INTRODUCED MARINE CHLOROPHYTE *CAULERPA TAXIFOLIA*.** R.A. Woodfield and K.W. Merkel, Merkel & Associates, Inc., 5434 Ruffin Rd., San Diego, CA, 92123

3:00 Break

53. 3:20 **EXOTIC AQUATIC TURTLES ON THE WEST COAST: CONSIDERATIONS AND IMPLICATIONS.** Mark R. Jennings (1), Dan C. Holland (2) and Robert H. Goodman, Jr. (3). (1) Rana Resources, 39913 Sharon Avenue, Davis, CA 95616 (2) 334A East Fallbrook Street, Fallbrook, CA 92028 (3) Citrus Community College, 1000 W. Foothill Blvd., Glendora, CA 91741

54. 3:40 **EXOTIC FISH SPECIES AND THEIR IMPACTS ON SMALL COASTAL LAGOONS IN SOUTHERN CALIFORNIA.** Camm C. Swift[1] and Dan C. Holland[2]. Emeritus, Section of Fishes, Natural History Museum of Los Angeles County, Los Angeles, CA 91007; and 334A East Falbrook, Fallbrook, CA 92028

55. 4:00 **INVADER IN THE OPEN SEA! THE NEW ZEALAND MARINE *SNAIL PHILINE AURIFORMIS* IN SOUTHERN CALIFORNIA COASTAL WATERS.** D. B. Cadien, Marine Biology Lab, County Sanitation Districts of Los Angeles County, 24501 S. Figueroa St., Carson, CA, 90745

56. 4:20 **INTERACTION BETWEEN NATIVE FISH, HABITAT, AND EXOTIC FISH SPECIES IN THE MIDDLE SANTA ANA RIVER, SOUTHERN CALIFORNIA.** Camm C. Swift, Emeritus, Section of Fishes, Natural History Museum of Los Angeles County, Mailing address: 346 West Le Roy Avenue, Arcadia, CA 91007

Saturday June 8
Location: Pickford Auditorium

Symposium: Rocky Reef Monitoring

Chair: Dan Pondella, Vantuna Research Group, Occidental College and Robert Grove, Southern California Edison.

8:45 **WELCOME AND INTRODUCTION.** D Pondella and R. Grove

57. 9:00 **MONITORING OF NEARSHORE MARINE HABITATS FOLLOWING BEACH REPLENISHMENT ACTIVITIES.** L. Honma[1] and R. Rundle[2]. [1]AMEC Earth & Environmental, 5510 Morehouse Dr., San Diego, CA 92121. [2] San Diego Association of Governments, 401 B Street Suite 800, San Diego, CA 92101.

58. 9:20 **ANALYSIS OF AERIAL PHOTOGRAPHS TO DETERMINE THE EFFECTS OF THE DIABLO CANYON POWER PLANT THERMAL DISCHARGE ON KELP CANOPIES.** Scott Kimura and James Strampe (TENERA Environmental, San Luis Obispo, CA 93401)

59. 9:40 **INTERPRETING HISTORICAL RECORDS OF SIZES OF KELP BEDS (PART 1).** W. J. North., W.M. Keck Engineering Laboratories, California Institute of Technology, Pasadena, CA, 91125

10:00 **INTERPRETING HISTORICAL RECORDS OF SIZES OF KELP BEDS (PART 2).** W. J. North., W.M. Keck Engineering Laboratories, California Institute of Technology, Pasadena, CA, 91125

60. 10:20 **UPDATE ON THE SAN CLEMENTE ARTIFICIAL REEF PROGRAM.** R. Grove, Southern California Edison; S. Schroeter, UCSB.

10:40 Break

11:00 **Plenary Speaker: Gregor Hodgson, U.C.L.A. on "John Q. Public Saves Coral Reefs." Pickford Auditorium**

12:00 LUNCH

61. 1:20 **REEF–A VOLUNTEER FISH MONITORING PROGRAM IN CALIFORNIA.** C.V. Pattengill-Semmens. Reef Environmental Education Foundation, P.O. Box 246, Key Largo, FL 33037, 206-529-1240, christy@reef.org

62. 1:40 **LONG-TERM CHANGES IN FISH POPULATIONS IN THE VICINITY OF DIABLO CANYON POWER PLANT, CENTRAL CALIFORNIA.** J.C. Carroll and J.R. Steinbeck. Tenera Environmental, 225 Prado Rd., Suite D, San Luis Obispo, CA, 93401.

63. 2:00 **DECLINES IN ROCKY REEF FISH POPULATIONS: HAVE DIFFERENT SPECIES RESPONDED SIMILARLY TO ENVIRONMENTAL CHANGE?** A. Brooks, R. Schmitt, & S. Holbrook. Marine Science Institute, University of California Santa Barbara, Santa Barbara, California, 93106 USA

64. 2:20 **LONGTERM DECLINE OF ICHTHYOPLANKTON ABUNDANCE IN SANTA MONICA BAY.** D.J. Pondella, II. Vantuna Research Group, Occidental College, Department of Biology, Los Angeles, CA, 90041.

65. 2:40 **REGIME SHIFTS IN CALIFORNIA CURRENT ZOOPLANKTON ASSEMBLAGES.** M.D. Ohman[1] and B.E. Lavaniegos[1,2]. [1]Integrative Oceanography Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0218, and [2]CICESE, Ensenada, Mexico

3:00 BREAK

66. 3:20 **MONITORING SUBTIDAL COMMUNITY CHANGES AT SURVEY ROCK, ANACAPA ISLAND: FORTY YEARS AND STILL COUNTING.** J. Engle[1], J. Altstatt[2], R. Ambrose[3], J. Carroll[4] and J.A. Coyer[5]. [1] Marine Science Institute, University of California, Santa Barbara, CA 93106; [2]Santa Barbara ChannelKeeper, 120 W. Mission St., Santa Barbara, CA 93101; [3]Department of Environmental Engineering, University of California, Los Angeles, CA 90024; [4]Tenera Environmental, San Luis Obispo, CA 93401; [5]Dept. of Marine Biol. University of Groningen, The Netherlands

67. 3:40 **THE NEARSHORE FISH ASSEMBLAGE OF THE SAN DIEGO/LA JOLLA ECOLOGICAL RESERVE.** Craig, M. T., P. A. Hastings, And P. K. Dayton. Scripps Institution Of Oceanography, 9500 Gilman Dr. Mail Code 0208, La Jolla, Ca 92093-0208.

68. 4:00 **REMOTE TRACKING OF GIANT SEA BASS (*Stereolepis gigas*) USING AN ACOUSTIC SENSORY ARRAY AROUND ANACAPA ISLAND.** Michael L. Domeier. Pfleger Institute of Environmental Research, 901-B PIER View Way, Oceanside, CA 92054

69. 4:20 **SEXUAL DICHROMATISM AND SPAWNING BEHAVIOR OF THE KELP BASS, *PARALABRAX CLATHRATUS*, FROM SANTA CATALINA ISLAND, CALIFORNIA.** B.E. Erisman. Nearshore Marine Fish Research Program, Department of Biology, California State University, Northridge, CA, 91330-8303

70. 4:40 **REPRODUCTIVE BEHAVIOR AND MATING SYSTEM OF THE TEMPERATE WRASSE, *HALICHOERES SEMICINCTUS*.** M.S. Adreani. Nearshore Marine Fish Research Program, Department of Biology, California State University, Northridge, CA, 91330.

Saturday June 8
Location: Bauer 35

Contributed Papers

Chair: Dr Raymond Wilson and Dr. David Huckaby, CSU Long Beach

71. 9:00 **PUTATIVE FUNCTION OF TYROSINE D OF PHOTOSYSTEM II PROBED BY FLUORESCENCE AND OPTICAL ABSORBANCE SPECTROSCOPY.** Jennifer H. Jones and Richard J. Debus. Department of Biochemistry, University of California, Riverside, CA 92521.

72. 9:20 **FIELD VALIDATION OF CHRONIC SUBLETHAL DREDGED MATERIAL LABORATORY BIOASSAYS: PROGRAM DESIGN.** M.A.Irwin, D.W. Moore. MEC Analytical Systems Inc. 2433 Impala Drive Carlsbad, CA 92008. T.S. Bridges. Waterways Experiment Station, U.S. Army Corps of Engineers, 3909 Halls Ferry Road, Vicksburg, MS, 39180

73. 9:40 **FLOWER DENSITY EFFECTS ON POLLINATION OF ARTICHOKE THISTLE (*Cynara cardunculus* L. Asteraceae).** L. Clarke and S. Banack, California State University, Fullerton, Department of Biological Sciences, Fullerton, CA 92834-6850

74. 10:00 **COPPER TOLERANCE AND REMEDIATION POTENTIAL OF *SALIX LASIOLEPIS*: A NATIVE CALIFORNIA WILLOW.** CM Vadheim, K Williams, J. Roberts. Department of Biology, CSU Dominguez Hills, Carson CA 90747.

75. 10:20 **WHAT DOES IT TAKE TO BE A HERBIVORE?–GUT STRUCTURE AND FUNCTION IN THREE SPECIES OF NEW WORLD SILVERSIDE FISHES (TELOSTEI: ATHERINOPSIDAE) WITH DIFFERENT DIETS.** M.H. Horn, A. Gawlicka, E.A. Logothetis, A.M. Jones, J.W. Cavanagh, D.P. German and C.T. Freeman. Department of Biological Science, California State University, Fullerton, CA, 92834

10:40 Break

11:00 **Plenary Speaker: Gregor Hodgson, U.C.L.A. on "John Q. Public Saves Coral Reefs." Pickford Auditorium**

12:00 LUNCH

30. 1:20 **PHYLOGENY AND BIOGEOGRAPHY OF THE SERANNID FISH GENUS *EPINEPHELUS*.** M. T. Craig. Scripps Institution of Oceanography. 9500 Gilman Dr. Mail Code 0208, La Jolla, CA 92093-0208.

76. 1:40 **FEEDING PREFERENCES AND ASSIMILATION EFFICIENCIES IN THE HERBIVOROUS MARINE SNAIL *LITHOPOMA UNDOSUM* (TURBINIDAE).** Erin Cox and Steve Murray, 800 N. State College, California State University, Fullerton, CA, 92834-6850

77. 2:00 **WHENCE HAVE THEY COME, THE ABYSSAL GRENADIERS?** Raymond R. Wilson, Jr. and Phoebe Attia, California State University, Long Beach, Department of Biological Sciences, Long Beach, CA 90840

78. 2:20 **PHYSIOLOGICAL RESPONSES TO VARIATIONS IN SALINITY AND NUTRIENTS BY THE BLOOM-FORMING MACROALGA *Enteromorpha intestinalis*: IMPLICATIONS FOR USE AS A BIOINDICATOR OF FRESHWATER AND NUTRIENT INFLUX TO ESTUARINE AND COASTAL AREAS.** R. A. Cohen and P. Fong. University of California, Department of Organismic Biology, Ecology and Evolution, Los Angeles, CA, 90095-1606.

79. 2:40 **THE USE OF AQUATIC INVERTEBRATES TO IDENTIFY ECOLOGICAL TRENDS IN URBAN FRESHWATER STREAMS.** W.H. Isham. MEC Analytical Systems, Inc. Carlsbad, CA, 92008.

3:00 BREAK

80. 3:20 **COMPARISON OF FEEDING GUILD STRUCTURES OF INTERTIDAL FISHES FROM CALIFORNIA AND CHILE: A MEASURE OF COMMUNITY CONVERGENCE.** K. S. Boyle and M. H. Horn. Department of Biological Science, California State University, Fullerton, Fullerton, CA 92834-6850

81. 3:40 **DIGESTIVE ENZYME ACTIVITY IN HERBIVOROUS AND CARNIVOROUS PRICKLEBACK FISHES (Stichaeidae): ONTOGENETIC AND PHYLOGENETIC EFFECTS.** D.P. German, M.H. Horn, and A. Gawlicka. Department of Biological Science, California State University, Fullerton, CA 92834

99. 4:00 **INFLUENCES ON THE SELECTION OF SCIENCE AS A STUDY AND CAREER.** Lisa Marin-Burkhart, Claremont Graduate University

SATURDAY June 8
Location: Burns Lecture Hall

Symposium: Research Training Program Presentations

Chair: Richard and Martha Schwartz, Torrance High School and L.A. County Schools

8:30 **Welcome and Introduction.** Gloria Takahashi

82. 8:45 **ANALYSIS OF PROTEOLYTIC ACTIVITY OF THE CARNIVOROUS PLANT *NEPENTHES*.** Jason Bae. California State University, Fullerton, Department of Biological Science, Fullerton, CA 92831-3599

83. 9:00 **EFFECTS OF *IN-UTERO* COCAINE EXPOSURE ON THE DEVELOPING BRAIN.** Amruta Kulkarny and Dr. Lynne Smith, Harbor UCLA REI 30427 Via Rivera, Ranch Palos Verdes, CA 90275

84. 9:15 **NEUROANATOMIC OBSERVATIONS OF THE BRAIN IN AUTISM: NEUROIMAGING STUDIES USING THE TECHNIQUE OF COREGISTRATION.** C.K. Chen. Research and Education Institute, Harbor-UCLA Medical Center, Department of Radiology, Torrance, CA 90502.

85. 9:30 **ON THE EFFECT OF LIGHT INTENSITY ON THE ELECTRICAL CONDUCTIVITY OF FILAMENTOUS FUNGI.** A.G. Craig. SCJAC Research Training Program.

86. 9:45 **INTERNUCLEOSOMAL DNA CLEAVAGE DETECTED IN MK-801 INDUCED RATS BUT SHOW NO SIGN OF CASPASE-3 ACTIVATION IN CELL DEATH.** R. Deniskin* and D. Fujikawa*//. *Experimental Neurology Laboratory, VA Greater Los Angeles Healthcare System, Sepulveda Ambulatory Care Center and Nursing Home Unit, Sepulveda, CA 91343, U.S.A.; //Department of Neurology and Brain Research Institute, UCLA School of Medicine, Los Angeles, CA 90095, U.S.A.

87. 10:00 **URBANIZATION OF COASTAL WATERS B CONCOCTING HORMONAL CHAOS.** L.R. Patel and S.M. Bay, Southern California California Coastal Water Research Project (SCCWRP), Westminster, CA 92683.

88. 10:15 **CORRELATION DYNAMICS IN "CIRCUIT MOLECULES" WITH CHAOTIC LINKS.** J. Manasson and V. A. Manasson. WaveBand Corporation, Los Angeles, CA, 90501.

10:30 Break

11:00 **Plenary Speaker: Gregor Hodgson, U.C.L.A. on "John Q. Public Saves Coral Reefs." Pickford Auditorium**

12:00 Lunch Break

1:00 **INSIGHT INTO THE INTEL SCIENCE TALENT COMPETITION.** Student applicants from past year.

1:15 **REPORT ON THE AJAS MEETING IN BOSTON, FEB. 2002.** Student participants from this year.

89. 1:30 **DISTRIBUTION OF OXIDATIVE AND GLYCOLYTIC ENZYMES IN ELECTROCYTES OF PHYLOGENTICALL DIVERSE SPECIES OF FISH.** Edward Smetak, Jr., La Habra High, SCJAS RTP, and Dr. Glenn Kageyama, Mentor, California State Polytechnic University, Pomona, Department of Biological Sciences, Pomona, CA, 91768

90. 1:45 **THE EFFECT OF LIGHT ON THE ACCUMULATION OF THE NUCLEAR-ENCODED *psbA* BINDING PROTEINS IN VASCULAR PLANTS.** Monica Singh, Maya E. Mazon, Laura Arce and Amybeth Cohen, Dept. of Biological Science, California State University, Fullerton, CA 92834-6850

92. 2:15 **THE EFFECTS OF ENDOTHELIAL POLARITY AND ALZHEIMER'S DISEASE ON MONOCYTE MIGRATION IN THE HUMAN BRAIN.** Wei Liang. Alhambra High School, Alhambra, CA, 91801; University of Southern California, Department of Biochemistry and Molecular Biology, Los Angeles, CA

93. 2:30 **DNA STRUCTURE AFFECTS SODIUM BISULFITE CONVERSION OF NUCLEOTIDES.** D.M. Chen and C.L. Hsieh. University of Southern California/Norris Cancer Center, Department of Urology, Los Angeles, CA, 90033-0804.

94. 2:45 **THE EFFECTS OF UROKINASE-TYPE PLASMINOGEN ACTIVATOR (uPA) INHIBITION ON CRANIAL NEURAL CREST MIGRATION.** H.L. Marr and M.A.J. Selleck. University of Southern California, Keck School of Medicine, Department of Cell and Neurobiology, Los Angeles, CA, 90089.

3:00 Break

95. 3:30 **GENETICS OF DAUER LARVAE FORMATION IN *CAENORHABDITIS BRIGGSAE*.** P. Shirley and I. Takao, California Institute of Technology, Department of Biology, Pasadena, CA, 91125.

96. 3:45 **RETROVIRAL-MEDIATED TRANSFER AND EXPRESSION OF THE NEOMYCIN AND HYGROMYCIN B DRUG RESISTANCE GENES.** Annie Li and Vicky Sung, Dr. Michael Lai Research Group, University of Southern California School of Medicine, Department of Molecular Biology and Immunology, Los Angeles, CA, 90033

97. 4:00 **BROCA'S AREA'S CRITICAL ROLE IN IMITATION.** Jake Marcus, Crossroads School, Santa Monica, CA, 90404, Marc Heiser, UCSF, San Francisco, CA, 94143, Fumiko Maeda, Marco Iacoboni, Ahmanson Lovelace Brain Mapping Center, Los Angeles, CA, 90095

98. 4:15 **OXIDATION OF SUBSTIUTED PHOSPHINES WITH SINGLET OXYGEN: INTRA- VS. INTER- MOLECULAR PATHWAYS.** Timothy Dong, Dr. Matthias Selke, California State University, Los Angeles, Dept. of Chemistry, Los Angeles, CA 90032

ABSTRACTS

1 SEDIMENT TOXICITY IN THE SOUTHERN CALIFORNIA BIGHT: 1998 REGIONAL MONITORING

S.M. Bay, Southern California Coastal Water Research Project, Westminster, CA, 92683; D. Lapota, Space and Naval Warfare Systems Center, San Diego, CA; J. Anderson, Columbia Analytical Services, Vista, CA; T. Mikel, Aquatic Bioassay and Consulting Laboratories, Inc., Ventura, CA; and J. Armstrong, Orange County Sanitation District, Fountain Valley, CA

Sediment from 303 sites on the continental shelf between Point Conception, California, and the United States-Mexico international border was sampled in 1998 using a stratified random design. Toxicity was evaluated using three methods: amphipod (*Eohaustorius estuarius*) survival, the P450 human reporter gene system (HRGS) test, and inhibition of phytoplankton (*Gonyaulax polyedra*) bioluminescence (QwikSed). Amphipod toxicity was most prevalent in bay and harbor areas, where 13–39% of the area (depending upon the stratum) was toxic. The QwikSed test was the most sensitive of the toxicity indicators. HRGS gene activity was induced by sediment extracts from 30 stations, with most of the induction produced by samples from port/industrial or marina areas. The QwikSed test results were not correlated with either amphipod survival or HRGS response and the correlation between HRGS and amphipod survival was significant but low ($r = 0.285$). The three test responses were combined into an integrated assessment of sediment quality. The integrated assessment identified 19% (651 km^2) of the SCB as areas of potential or high concern. Areas of high concern (2.1%) were almost exclusively located within harbors and bays, while areas of potential concern were present in all strata tested. Temporal differences in toxicity were apparent in San Diego and offshore mid-depth areas.

2 IDENTIFICATION OF CONTAMINATED SEDIMENTS IN THE SO. CALIF. BIGHT USING A BIOMARKER ASSAY (RGS; EPA METHOD 4425)

J. W. Anderson, J. M. Jones, D. McCoy, Columbia Analytical Services and E. Zeng, J. Noblet, So. Calif. Coastal Water Research Project (SCCWRP)

Samples from Bight '98 were extracted at the SCCWRP laboratory and extracts from 267 stations were sent to Columbia Analytical Services for testing with the human reporter gene system (HRGS), now called EPA method 4425. Small amounts (2–20: L) of the extracts are applied to replicate culture wells with about 1 million transgenic cells. If CYP1A-inducing compounds (PAHs, PCBs, dioxins, furans) are present in the extract the cells produce a luminescent enzyme as a function of the concentrations and potencies of the compounds. The responses to the sediment extracts were reported as μg of Benzo[a]pyrene equivalents per g dry weight. When the PAH analyses were available, total PAHs were plotted against the 4425 data. The regions evaluated in this comparison were north, central, south, Santa Monica Bay, San Diego, embayments, rivers, and POTWs. Correlation coefficients for all regions, except the northern Bight, were significant (r^2 values from 0.63 to 0.87). Two stations on the Palos Verdes shelf were above the curve suggesting contributions from PCBs or other inducing compounds. There was no correlation between the measured PAHs and the 4425 responses in the northern Bight, and the highest value observed (900 μg/g B[a]PEq) was from Coal Oil Point, an oil seep area. These findings suggest that petroleum compounds other than those normally measured may be CYP1A inducers. Overall, the findings from the 4425 testing provide an excellent signal for the need for further investigation and monitoring of sites where there is the potential for chronic ecological effects.

3 THE SPATIAL DISTRIBUTION OF SEDIMENT CONTAMINATION IN THE SOUTHERN CALIFORNIA BIGHT

J.A. Noblet and S.L. Moore. Southern California Coastal Water Research Project, Westminster, CA, 92683-5218

The results from the sediment chemistry analyses performed as part of the 1998 Regional Marine Monitoring Study are presented. A total of 361 samples of surface sediments (0–2 cm) were collected;

including 290 stations in United States waters from Point Conception to the US-Mexico border, and 71 stations from Mexican waters off of Baja California. Sampling stations were selected using a stratified random sampling design. The individual strata selected for study included both geographic and anthropogenic associations. Sediment samples were analyzed for TOC, TN, grain size, trace metals, Chlordane, DDT, PAHs, and PCBs. The results show that 85% of the bight area is contaminated by at least one organic pollutant, and 50% of the bight area sediments are enriched in at least one trace metal. The overall result is that 88% of the bight area sediments are contaminated by at least one anthropogenic pollutant. Although the contamination is widespread, the concentrations of most target analytes are low relative to sediment quality guidelines over a large majority of the bight area. Higher levels of sediment contamination are localized in proximity to past or present point sources, and/or are related to specific anthropogenic activities.

4 A HISTORICAL VIEW OF MARINE SEDIMENT CONTAMINATION SURVEYS IN SOUTHERN CALIFORNIA FROM 1977 TO 1998

Richard Gossett. CRG Marine Laboratories, Inc., Torrance, CA, 90501

Selected stations from the near-coastal marine sediments of Southern California were surveyed periodically for trace contaminant levels in1977, 1985, 1990, 1994, and 1998 as part of the Southern California Coastal Water Research Project's Reference Surveys and the Bight Surveys. The chemical analyses were essentially performed by the same personnel for all the surveys and offers a unique opportunity to view the historical changes in both the contaminant trends but also in the methodology used over this 21 year time period.

5 MUSSEL MANIA: LONGTERM CONTAMINANT TRENDS IN THE SOUTHERN CALIFORNIA BIGHT

A.J. Mearns and T. P. O'Connor. National Oceanic and Atmospheric Administration, Seattle, WA and Silver Springs, MD

Twenty one of the over 260 inter-tidal NOAA National Mussel Watch stations are located in the Southern California Bight and most are located adjacent to regional monitoring grids. Mussels have been collected and analyzed annually or biennially since 1986. Concentrations of DDT, other organochlorine pesticides, tributyl tin, and PCB's continued to decline throughout the Bight during the 1990's, following major rapid decreases that occurred between 1965 and 1985. Palos Verdes is no longer "the" hot spot with respect to DDT or PCB's; mussels near marinas and harbors are the most contaminated with PCB's and chlordane. Levels of organochlorines at distant urban stations, such as Point Dume, are now nearly equivalent to those at remote sites. Organochlorines in mussels are 100-times less contaminated than they were in the early 1970's, and ten times cleaner than in the early 1980's. They also may be cleaner than at any time since World War II. Concentrations of polycyclic aromatic hydrocarbons (PAH's) remain one or more orders of magnitude higher in bays and harbors than along the coast. Fingerprinting suggests the dominant source is combustion, not oil spills. Contaminant concentration trends in mussels no longer are related to trends in wastewater emissions. Other factors controlling contaminant variability include year-to-year variations in storm-water runoff, marina flushing and episodic oceanic events. Further treatment and industrial source control of wastewater effluents will provide no further benefit in reducing coastal contamination whereas control of surface water runoff, atmospheric inputs and marina/vessel-related sources may.

6 A REVIEW OF THE KELP BEDS OF ORANGE AND SAN DIEGO COUNTIES AND THEIR RESPONSE TO EL NIÑOS AND LA NIÑAS FROM 1967 TO 2001

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In 1985, the San Diego Regional Water Quality Control Board (Board) stipulated in permits it issued that kelp beds near each major discharger into the Pacific Ocean be photographed annually by means of vertical and aerial infrared photography, to record as best possible the maximum areal extent of any canopies present among the 24 distinct beds that occur offshore of Orange and San Diego Counties. A consortium of dischargers was formed to develop a plan with the Board that would fulfill the prescribed requirements. Surveys were to be conducted several times per year to determine the maximum canopy extent for each year. As the surveyor selected, Dr. Wheeler J. North, had been independently assessing the kelp beds using this methodology since 1967, the historical data provided a solid foundation for the new data set.

The 34 year data set provides a synoptic view of the performance of 24 kelp beds. Although the intention was that a synoptic survey of the beds would allow a determination of the potential detrimental effects of waste water (both heated effluent and sanitary) on the kelp beds, it also provided insight as to the effects on the kelp beds from five major El Ninos and five major La Ninas that occurred during this period. Analysis of the data indicates that the kelp beds may respond strongly to both occurrences.

This total record can be subdivided into two periods, each exhibiting very different behavior. The history from 1967 up through 1979 consisted of relatively small fluctuations. The remainder, from 1980 onward, was characterized by large fluctuations ranging from a minimum of 0.379 km^2 in 1984 to a maximum of 16.868 km^2 in 1989. The minimum value corresponded to the final year of a major El Niño while 1989 represented the first year of a large La Niña that occurred during a large stimulatory period unmatched by anything else in the 34 year history. This was followed by the largest (by some factors) El Niño of the century in 1997–1998 that resulted in the loss of 98% of the kelp canopy coverage. A large La Niña in 1999–2000 effected a recovery to about 33% of the 1989 total.

Each of the 24 kelp beds of Orange and San Diego County were monitored during these anomalous events by the means of color aerial infrared photographs taken on a quarterly basis. These photographs were taken under as close to similar conditions as possible. From these photographs, the greatest areal extent of each of the separate kelp canopies was determined for each year. Based on these data, a synopsis of the health of each of the kelp beds and the effects of these environmental perturbations, as it compares with the other kelp beds in the region, can be determined. Although it is not possible to determine the cause of a decline or decrease in a single kelp bed by aerial photographs, it is effective at showing whether the bed in question is responding to an area wide event, or if an atypical pattern has manifested. This then becomes a very cost effective tool to determine where to focus additional concentrated efforts on beds that may be responding atypically.

7 LARGE SCALE OCEANOGRAPHIC STUDIES OF THE CONTINENTAL SHELF OF THE SOUTHERN CALIFORNIA BIGHT: THE EXAMPLE OF BIGHT 98 AND FUTURE APPROACHES

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Stormwater runoff, sewage discharge, aeolian input, and other sources contribute to the contamination of our coastal waters in the Southern California Bight. The Water Quality Group of the Bight 98 project undertook the task of examining the impact of stormwater runoff during the winter 1998–99. The study provides insights about the locations and magnitude of influence of stormwater and its relationship to the size of rainfall events. However, this study and other studies of contaminant input to the coastal ocean demonstrate the need for new types of sustained observations and new technology to observe components that characterize the contaminants and their fates in the coastal ocean. A combination of remote sensing, eularian and lagrangian measurements, various new technology coupled with data assimilation and modeling are required to understand the processes.

8 A HALF CENTURY OF PHYSICAL AND BIOLOGICAL OCEANOGRAPHY IN THE SOUTHERN CALIFORNIA BIGHT WITH EMPHASIS ON FISH SPECIES, TEMPERATURE AND ZOOPLANKTON

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The California Cooperative Fisheries Investigations sea surveys have collected, identified, and curated fish larvae from 40,000 quantitative ichthyoplankton samples. The majority of the common fishes represented as larvae in the CalCOFI ichthyoplankton time series have not been commercially fished.

These species represent a Acontrol@ in assessing the relative effects of fisheries and environment on the fish populations of the California Current region. We believe that a group of Pacific sardine inhabited the harbors and shores of the Southern California Bight for two decades following the collapse of the fishery in the 1960s. Beginning in 1992, the sardine population began to increase abruptly and has emerged as a dominant epipelagic species, with a distribution stretching from southern Baja California to Alaska. In contrast, the northern anchovy has withdrawn from its former widespread distribution in California Current waters to the inshore regions of the Southern California Bight. During the warm ocean regime (1977–1998) the CalCOFI larval fish time series has documented the introduction and population increase of common mesopelagic species from the Eastern Tropical Pacific and from equatorial and central water masses. The most continuous part of the CalCOFI surveys is in the shelf waters, slope waters and California Current from the Mexican Border to San Luis Obispo.

9 ASSESSMENT OF DEMERSAL FISH AND INVERTEBRATE ASSEMBLAGES ON THE SOUTHERN CALIFORNIA SHELF IN 1998

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A regional synoptic survey of demersal fish and invertebrates was conducted in 1998 on the continental shelf of the mainland (including bays) and islands of southern California. The objective of this study was to assess the status and health of fish and invertebrate populations and assemblages. In July–September 1998, 314 stations (5–200 m depth) were sampled from Point Conception, California to the U.S.-Mexico International Border and at most offshore islands using 7.6-m otter trawls. The survey collected 143 species of fish and 313 species of invertebrates. Fish and invertebrate populations varied most by depth, with population attributes generally being lowest on the inner shelf and highest on the outer shelf. Distinct assemblages occurred in different depth zones and in natural bays, with island assemblages showing some differences from mainland assemblages. Fish recurrent groups in 1998 (an El Niño year) differed considerably from those typical of cool and warm regime periods in the past. DDT in sanddab guild species exceeded predator-risk thresholds (14 ppb) in 71% of the area on the southern California shelf. PCB exceeded predator-risk thresholds for birds and mammals in 5–8% of the area. Relative to the early 1970s, fish and invertebrate assemblages on the southern California shelf in 1998 were relatively healthy but DDT levels in sanddab guild species may pose health risks to bird and mammal predators.

10 PAH EXPOSURE AND DNA DAMAGE IN FLATFISH FROM SOUTHERN CALIFORNIA BAYS AND HARBORS, AND CHANNEL ISLANDS

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Two species of flatfish from southern California were evaluated for exposure to polynuclear aromatic hydrocarbons (PAHs), and DNA damage. California halibut (*Paralichthys californicus*) were collected from eight bays and harbors (Ventura Harbor, Channel Islands Harbor, Marina del Rey, King Harbor, Alamitos Bay, Long Beach Harbor, Newport Bay, San Diego Bay), and a reference site off Camp Pendleton. Pacific sanddab (*Citharichthys sordidus*) were collected near four of the Channel Islands (San Miguel Isle, Santa Cruz Isle, Anacapa Isle, Santa Barbara Isle). PAH metabolites in fish bile were characterized using a semi-quantitative technique that measures fluorescent aromatic compounds (FACs) in fish bile. DNA damage in fish blood cells was assessed by measuring the amount of single-strand breaks in stained DNA using the Comet assay. The concentration of FACs was elevated in most fish from bays and harbors, with average concentrations ranging from three to ten times greater than FACs in reference fish. DNA damage varied by a factor of five among fish from bays and harbors. There was no evidence of elevated PAH exposure in the Pacific sanddabs from the Channel Islands. There was a significant association between FAC concentrations and DNA damage in California halibut at Marina del Rey and Ventura Harbor, but not at other locations.

11 PORTS OF LONG BEACH AND LOS ANGELES BIOLOGICAL MONITORING OF SAN PEDRO BAY

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Comprehensive surveys of Long Beach and Los Angeles Harbors in San Pedro Bay were conducted in the year 2000. These surveys represent the first harbor-wide examination of biological resources since the extensive studies of the 1970s. The surveys also examined a greater variety of resources than were examined in the more limited studies of smaller areas of the harbors in the 1980s and 1990s. Considerable changes have occurred in both harbors over the last couple of decades, including deepening of navigational channels, construction of landfills and basins, creation of shallow water habitats, and a continuation of pollution reduction measures begun in the 1960s. Results of the year 2000 surveys demonstrate that the harbors support diverse assemblages of fish, benthic invertebrates, aquatic vegetation, and birds. Although the year 2000 surveys were conducted during a period following substantial changes in oceanographic conditions (i.e., dissipation of a La Niña period following a strong El Niño event) and dredging and landfills in the harbors, the data demonstrate a continuation of an improvement in habitat quality since the severely polluted conditions of the 1950s.

12 SOFT-BOTTOM BENTHIC INVERTEBRATE ASSEMBLAGES OF THE SOUTHERN CALIFORNIA BIGHT

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We identified benthic assemblages and their associated habitat differences using data from 278 uncontaminated sites sampled in the Southern California Bight in 1998. Previously, two open coastal assemblages were identified from 1994 regional survey data; they separated on depth. We discriminated several additional assemblages primarily because we sampled additional habitats: Channel Islands, bays, and the Mexican coastal shelf. In bays, we identified two assemblages based on latitude; benthos from Dana Point Harbor to San Diego differed from those to the north and were structured by the mat-forming clam *Musculista senhousia.* The assemblage in northern bays resembled the previously identified shallow and mid-depth coastal assemblages, but was distinguished by a few species also present in the southern bays. We divided the coastal mid-depth assemblage described in 1994 into two based on sediment grain size; the portion associated with fine sediments was a subdivision of an assemblage also found at mid-depth on the Mexican shelf and at Catalina Island. Another, previously undiscriminated, assemblage occurred at Channel Islands sites and in coarse sediments at mid-depths on the Mexican shelf. Finally, we discriminated another assemblage that was widespread in very coarse, gravelly sediments. Our knowledge and understanding of benthos in the Southern California Bight increased substantially as a result of the broader sampling effort in 1998.

13 DIVERSITY-ABUNDANCE RELATIONSHIPS IN BENTHIC HABITATS OF THE SOUTHERN CALIFORNIA BIGHT

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For a comparison of benthic diversity-abundance relationships in three soft-bottom habitats, 321 samples were collected at random from southern California embayments, the coastal shelf and Channel Islands. Diversity was highest in the Channel Islands, intermediate on the coastal shelf, and lowest in embayments (means of 109, 66 and 42 taxa per $0.1m^2$ sample, respectively). Mean abundance on the coastal shelf was much lower than for Channel Islands and embayments (291, 651 and 658 per sample, respectively). Thus, benthos of the bays were highest in abundance but lowest in diversity. The diversity-abundance relationship for the coastal shelf was indistinguishable from that for the Channel Islands; the relationship was linear and both habitats accumulated a taxon for about every five organisms collected. The pattern for samples from the bays was more variable, less linear, and taxa accumulated at a slower rate; maximum abundance was nearly three times higher but numbers of taxa were only 65% of values for islands and the coast. Diversity-abundance ratios for bay benthos only correlated weakly with habitat variables but there was a significant ($p < 0.01$) correlation with abundances of non-indigenous species. The low diversity-abundance ratios in embayments are at least partly explained by a proliferation of invasive species.

14 HOW IMPORTANT ARE NONINDIGENOUS SPECIES TO THE BENTHOS OF SOUTHERN CALIFORNIA EMBAYMENTS?

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As part of the Bight '98 Regional Monitoring Program, 113 benthic samples were collected in southern California embayments to assess the prevalence and evaluate the effects of nonindigenous species. We found that nonindigenous species were prevalent throughout the area, occurring in all but one sample. Only 25 of the 625 species we collected were considered nonindigenous but they contributed an average of 10% of the species and 23% of the abundance in each sample. There was no apparent relationship between the numbers, proportions or composition of nonindigenous species populations and the type of vessel traffic. Three of the five most abundant species, *Pseudopolydora paucibranchiata, Musculista senhousia* and *Theora lubrica,* were nonindigenous; other nonindigenous species abundances were much lower. All three species were widespread. *M. senhousia* dominated southern embayments while *T. lubrica* dominated Los Angeles—Long Beach Harbor and Anaheim Bay. Large numbers of *P. paucibranchiata* occurred in every bay. The bivalve *M. senhousia* has the greatest effect on benthic habitats. The thick mats of byssal threads that it lays down add structure and create additional niche space for many other species. *P. paucibranchiata,* a polychaete worm, was the most abundant organism in Bight '98. It builds tubes that also add structure but which have less impact than *M. senhousia* because of their small size. *T. lubrica,* a small bivalve, has the least effect. It is likely that food webs today differ considerably from those existing before these invaders arrived.

15 MARINE–THE MULTI-AGENCY ROCKY INTERTIDAL NETWORK

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Regional, long-term monitoring programs provide data needed by a wide range of groups from the public and private sector. Coordinated programs provide the added benefits of a diversified funding source, better coordination among field researchers, data sharing and standardized field measurements. Regional monitoring programs allow smaller entities to evaluate local changes in the context of a broader system which is able to consider large-scale changes in the environment such as El Nino events. Ongoing monitoring importantly allows for early detection of environmental problems. It also provides a dynamic baseline of natural conditions prior to extreme events such as an oil spill. MARINE's focus is to determine the health of the rocky intertidal ecosystem in the Southern California area. Seastars, abalone, mussels, surfgrass, anemones, limpets, barnacles and several varieties of algae are monitored every fall and spring at established sites from San Luis Obispo County to San Diego County including the offshore islands. With ten years of data at 50 sites and 2–5 years of data at another 20 sites, changes which can be attributed to succession, recruitment and other broad patterns now emerge. Important collaborations with other large monitoring programs such as PISCO (Partnership for the Interdisciplinary Study of Coastal Oceans), provide the potential to answer important related questions not funded by MARINE. Critical to the success of the program is a core of academic biologists committed to ongoing monitoring and continued support by a core of agencies who value the data being collected and are willing to work toward a common product.

16 POST-RESTORATION LONG-TERM MONITORING FOR THE BATIQUITOS LAGOON ENHANCEMENT PROJECT

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Batiquitos Lagoon, a 234ha. closed, eutrophic lagoon in Carlsbad California was restored through a management partnership between the Port of Los Angeles and City of Carlsbad. Since the December 1996 opening of the restored lagoon to tidal circulation, Batiquitos Lagoon has been the subject of a 10-year monitoring program to track the development of the restored system.

Over the first five year of monitoring, the rates of change in both biological and physical environments have slowed and become relatively predictable. Normal seasonal patterns of abundance, richness, and diversity within fish and bird populations have developed at relatively rapid rates of one to two years following lagoon restoration. However, building sandbars at the lagoon entrance have adversely muted tidal dynamics throughout the lagoon resulting a compression of the tidal range and a general increase in the frequency of inundation of intertidal environments. As a result, intertidal marshlands are restricted to higher elevations than would normally occur in a fully tidal system and intertidal mudflats are less frequently and completely exposed than would be expected under fully tidal conditions. Subtidal eelgrass communities and coastal salt marshes have become dominant features of the lagoon following both natural expansion of marsh vegetation and introductions of California cordgrass and eelgrass to the system where both species have long been absent. The development of vegetation communities within the lagoon occurred through delayed and punctuated events following periods of physical and chemical environmental stabilization.

17 ATMOSPHERIC DEPOSITION OF TRACE METALS TO SANTA MONICA BAY

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There are numerous sources that contribute pollutants to Santa Monica Bay. Some sources (i.e. POTWs) are well-characterized and inputs to the Bay are well-known. Other sources, such as atmospheric deposition, have not been well-characterized and its inputs are almost completely unknown. Aerosol samples were collected for particulate mass and trace metal concentrations every six days throughout one year in the Santa Monica Bay watershed and at eight satellite locations within the airshed, but outside of the watershed. Samples of wet deposition were collected for the entire wet season. Finally, seasurface microlayer samples were collected across a grid of stations to determine the amount of surface area affected by atmospheric deposition. Concentrations of metals were lowest at the Santa Monica Bay site relative to other sites in the airshed and most deposition was likely from sources within the watershed. Aerial deposition had some impact on Bay water quality; trace metal concentrations were enriched as much as 80-fold in the seasurface microlayer across one-third of the Bay. Most deposition occurred during dry weather; wet deposition represented as little as 2% of the total annual load for most metals. Atmospheric deposition of chromium, copper, nickel, lead, and zinc using a locally-developed atmospheric transport and deposition model were 15, 38, 53, 3, and 167 metric tons annually, respectively. These estimates represent between 40 and 60% of the combined mass emissions from all sources including POTWs, industrial discharges, and urban runoff.

18 CHARACTERISTICS, FORMATION MECHANISMS AND CHEMICAL COMPOSITION OF ULTRAFINE PARTICLES IN VARIOUS LOCATIONS OF THE LOS ANGELES BASIN

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Ultrafine particulate matter (PM) consists of particles mostly emitted by combustion sources as well as formed during gas-to-particle formation processes in the atmosphere. Various studies have shown these particles to be particularly toxic. The very small mass of these particles has posed a great challenge in determining their size-dependent chemical composition using conventional aerosol sampling technologies. This paper presents results from a study conducted in two urban areas of Southern

California in order to examine the effect of different sources and formation mechanisms on the size distribution and temporal trends of ultrafine particles. From semi-continuous measurement of size distribution of ambient aerosols as well as time-integrated sampling of particles, the temporal and diurnal trends in the behavior of ultrafine particles were conducted to better understand the formation mechanisms in different locations of an urban metropolitan area. Results showed that a western site, located in central Los Angeles, is appropriately characterized as a source site with constant primary emissions. In contrast, ultrafine and accumulation modes PM in a receptor site were found to originate mostly from secondary reactions, which are more pronounced during the warmer months of the year particularly during the warmer season of the year, between April through October. The differences observed in the ultrafine particle distribution and temporal trends clearly demonstrated that mechanisms other than direct emissions play an important role in the formation of ultrafine particles in receptors sites of the Los Angeles Basin.

19 AUTOTOMY: NOVEL PROTECTION FROM MERCURY TOXICITY IN AQUATIC OLIGOCHAETE WORMS

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Aquatic oligochaete worms are commonly used as tools in toxicity testing as well as in sediment's health assessments. Oligochaete worms are generally considered pollution tolerant, but little research has been made to help us understand the mechanisms used by these "tolerant" worms to survive pollutant exposure. The present research suggests that changes in the behavior of tolerant worms are an important component of the many levels of response to contaminants that promote the worms' survival. We investigated autonomy behavior (reflex action by which the tail segments of the worms brake off and the missing segments are later regenerated) in *Sparganophilus pearsei* worms as a reaction to mercury stress. The behavior was assessed and compared among three populations with different mercury sensitivities. Mercury accumulation in different body segments was measured. The results of these experiments suggest these worms may use autotomy as a mechanism of mercury detoxification.

20 EQUAL LOADS OF NUTRIENTS ADMINISTERED TO MACROALGAE VIA PULSES OF DIFFERING FREQUENCY AND MAGNITUDE AFFECT GROWTH AND TISSUE NUTRIENTS OF *ENTEROMORPHA INTESTINALIS* AND *ULVA EXPANSA*

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Macroalgae such as *Enteromorpha intestinalis* and *Ulva expansa* are highly successful in estuarine systems, in which nutrient inputs can range from chronic, daily loads to episodic pulses. We investigated the effect of the timing of nitrogen (N) supply on the growth and tissue nutrient dynamics of *E. intestinalis* and *U. expansa* while holding N supplies constant. Over a 28-day period, algae were given equal supplies of NO_3-N (1988 mmol, or 28 mg) via pulses of different magnitude and frequency. Doses given to 10 g of algae in 1 L seawater were: 71 mmol (1 mg) daily, 497 mmol (7 mg) weekly, 994 mmol (14 mg) bi-weekly, or 1988 mmol (28 mg) monthly. Phosphorus was also added in a 10: 1 (molar) ratio. Growth was highest for both species when N was added most frequently (daily). Tissue N and P content were also highest when nutrients were added daily. Overall, *E. intestinalis* grew more than *U. expansa,* however *U. expansa* had much greater tissue N content than *E. intestinalis. E. intestinalis* and *U. expansa* displayed extremely high uptake rates over the course of the experiment. Within 24 h, both algae depleted the water column of the first daily dose, and in the other treatments, *E. intestinalis* removed 460–580 mmol NO_3 from the water column, and *U. expansa* removed 510–910 mmol NO_3. The ability of these species of algae to take advantage of increased frequency of nutrient supply may, in part, explain their success in coastal systems subject to chronic nutrient inputs.

21 MORPHOLOGICAL VARIATION AND PATTERNS OF REPRODUCTION AND RECRUITMENT IN LOWER INTERTIDAL POPULATIONS OF THE KELP *EGREGIA MENZIESII* (TURNER) ARESCHOUG

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Egregia menziesii (O. Laminariales) is an important habitat-structuring component of shallow, benthic communities throughout central and southern California. Morphological variation in this species is high, particularly in the lateral blades that distichously cover the flattened branches. Fertile sporophylls are believed to be produced throughout the year, but to be most abundant between April and November. However, spatial and temporal patterns of thallus morphology and sporophyte reproduction have not been investigated in Southern California. We studied lower intertidal populations of *E. menziesii* at three southern California sites separated by <16 km. Growing axes (n = 9) were collected monthly to quantify sporophyll production and the frequencies of different types of lateral blades. Band transects were surveyed quarterly to determine temporal patterns of sporophyte recruitment. Sporophylls were found throughout the year, but sporophyll densities showed a strong peak in winter (December) at all three sites. Sporophyte recruitment began in late February and peaked in June, suggesting a gametophyte period of approximately 6 months. Lateral blade morphology at the three sites varied in a consistent pattern and was related to axis length; most thalli initially developed spatulate lateral blades and then produced narrower, filiform laterals. Thalli subjected to intense grazing pressure had shorter axes and were dominated by spatulate blades, while those growing under low grazing pressure exhibited longer branches, densely covered with filiform laterals. Observed changes in the frequencies of morphologically variable lateral blades along *E. menziesii* axes hypothetically affect productivity, susceptibility to grazing, and thallus drag in this shallow water kelp.

22 HABITAT ASSOCIATIONS OF STEELHEAD TROUT IN A SMALL STREAM NEAR THE SOUTHERN EXTENT OF THEIR RANGE

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Habitat associations of steelhead trout *Oncorhynchus mykiss* are generally well known for populations in northern territories, but nearly nothing has been documented concerning habitat associations of steelhead in southern landscapes. I assessed use of microhabitat and mesohabitat by three age groups of wild juvenile steelhead in a small coastal stream in south-central California (35° N). The objectives of this study were to describe use of various habitat types (run and pool) and characteristics (depth and velocity), and to investigate relationships between spatial variation in density of juvenile steelhead and habitat properties (depth, habitat area, riparian canopy and density of older conspecifics). Generally, the results show that use of habitat by juvenile steelhead was size or age dependent, and was influenced by water depth and to a lesser extent focal point velocity. Spatial variation in the density of the age groups was related to the arrangement of certain habitat properties; large deep pools may be valuable in particular to age-1 and older steelhead. Because the habitat used by age-0 steelhead may not necessarily be suitable for age-1 and older steelhead, the findings support the belief that multiyear freshwater residence of steelhead requires habitat that is appropriate for all age groups.

23 *IN SITU* MONITORING OF GASTRIC pH CHANGES ASSOCIATED WITH FEEDING IN LEOPARD SHARKS

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Surprisingly little is known about feeding periodicity in sharks. We monitored changes in gastric pH as a possible indicator of feeding in leopard sharks (*Triakis semifasciata*). An adult leopard shark was fed a pressure insensitive pH probe with attached data-logger (110 mm × 10 mm – 80 g) and was subsequently fed different rations of squid over a 14 d period. The stomach remained strongly acidic over the duration of the experiment, except during feeding bouts, which resulted in a rapid increase in pH followed by a gradual decrease until returning to pre-prandial levels (mean pH 1hr before meal was 1.6 ± 0.04 (SD), 1hr after meal was 2.71 ± 0.51). Ration size was positively correlated with the time needed for gastric pH to return to pre-prandial levels. To determine the effects of the probe on gastric pH, stomach fluid samples were taken from 10 non-instrumented sharks at different time intervals after being fed a meal of squid. Gastric pH increased to 3.32 ± 0.38 1-hr after feeding and gradually decreased to 2.04 ± 0.27 after 72-hr. These data support *in situ* observations made using the probe and suggest that pH changes could be used to determine feeding events in the wild.

24 ONTOGENETIC RESPONSES TO TERRESTRIAL DIETS IN A NEOTROPICAL FISH: GUT MORPHOLOGY AND DIGESTIVE ENZYME ACTIVITY IN *BRYCON GUATEMALENSIS* (CHARACIDAE)

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The characid fish *Brycon guatemalensis* consumes insects as juveniles and fruits and leaves as adults. Gut structure and function may be expected to change with this ontogenetic shift from carnivory to herbivory. So, we compared gut length (in progress), pyloric caeca number and arrangement (in progress), and biochemical activity of four digestive enzymes (pepsin, trypsin, amylase and lipase) in juvenile (40–80 mm SL) and adult (242–414 mm SL) fish collected from the Rio Puerto Viejo, a tropical rain forest stream in northeastern Costa Rica. Activities (IU/ g tissue) of pepsin and trypsin were significantly higher in juveniles than adults, whereas amylase activity was significantly greater in adults than juveniles. Lipase activity did not differ between age classes. Our results at this point show that the differences between juveniles and adults in gut length and digestive enzyme activities match those expected for carnivores vs. herbivores and indicate that *B. guatemalensis* is ontogenetically specialized to digest each component of its terrestrial diet.

25 DIEL MOVEMENT PATTERNS OF THE OCEAN SUNFISH, MOLA MOLA: A PRELIMINARY REPORT

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We used temperature and depth-sensing acoustic transmitters to track the movements of four ocean sunfish near Catalina Island, California. We tracked fish continuously for 24–48 h periods, and concurrently deployed a CTD every 90 minutes to characterize the water column. Geographical position was determined by GPS at 3-minute intervals during tracks, and was analyzed in relation to fish depth and temperature, oceanographic data, and time of day. Ocean sunfish traveled a mean distance of 30.11 ± 9.16 km over a 24 h period. Rate of movement was significantly lower for 6 hours following sunset ($p<0.001$) than at other times of day. Ocean sunfish inhabited depths ranging from the surface to 392 m, and generally displayed a trend towards diel vertical migration. The diel depth distribution patterns of ocean sunfish may make them highly susceptible to the drift gillnet fishery off southern California, of which they comprise 26% of the total catch.

26 INCIDENCE OF *SALMONELLA* IN FREE RANGING IGUANID LIZARDS OF SOUTHERN CALIFORNIA

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Considerable study has been devoted to investigating the incidence of *Salmonella* in the gut of captive reptiles, however limited data are available for free ranging populations. This study investigated the frequency of *Salmonella* in cloacal samples drawn from five species of southern California iguanid lizards: *Sceloporus occidentalis longipes, S. g. graciosus. S. o. orutti, S. magister uniformis,* and *Uta stansburiana. Sceloporus occidentalis* was the principle species of investigation. In samples drawn from 96 specimens, 55% (N = 33) of females, and 41% of males (N = 63) tested *Salmonella* positive. No positive tests were found in cloacal swabs taken from *S. graciosus* (N = 20), nor *U. stansburiana* (N = 10). *Salmonella* was found in three of four specimens of *S. orcutti.*

When juvenile lizards are omitted from the frequency calculations for *S. occidentalis, Salmonella* presence was found to differ significantly different between the sexes ($P<0.05$). Further, *Salmonella*-infected female *S. occidentalis longipes* were found to be significantly larger in body mass ($P<0.02$), than non-infected females. Males appear to be larger as well, however the differences were only significant at the 0.10 probability level. Causality for the difference in body size is explored and is proposed as a topic for future study.

27 OIL IMPACT ON GROWTH OF *SALICORNIA VIRGINIA* UNDER CONTROLLED TIDAL CONDITIONS

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Salicornia virginica is a slow growing salt marsh plant species that grows at the lower marsh elevations. In a greenhouse experiment, *S. virginica* plants were exposed to an oil treatment of 2 L/m^2 in a microcosm that included a tidal regime, which inundated the plants twice daily. In a six-week experiment we examined plant biomass and succulence under oiled and control conditions. In a twelve-week experiment we examined the growth of *S. virginica* under oiled and control conditions. Additionally we examined the ability of *S. virginica* to recover from oiling by moving plants exposed to oil for six weeks to a clean microcosm for the remaining six weeks. After six-week exposure, shoots and roots were not significantly affected. Shoot succulence, however, was negatively affected by oil. Additionally, there was a significant interaction between the effects of oiling and inundation levels on shoot succulence, indicating a beneficial effect of tidal washing during oil contamination. All *S. virginica* exposed for twelve weeks died, shoots were 100% senesced. Those transplanted from the oiled to the clean microcosm after six weeks to recover for an additional six weeks showed growth of green shoots at the terminal end of the shoots affected during the six weeks of oiling. *S. virginica* after twelve weeks of oiling had all senesced. Roots after six-week recovery showed limited re-growth following their six-week oiling. First physiological impact on *S. virginica* affects its succulence. It can recover after at least six weeks of oil exposure.

28 EXAMINATION OF RECRUITMENT PATTERNS IN KELPBASS, *PARALABRAX CLATHRATUS*, BY THE ANALYSIS OF MITOCHONDRIAL DNA CONTROL REGION SEQUENCES

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Potential benefits of marine protected areas (MPA) include increased biomass, species diversity, and enhanced recruitment to the MPA and to adjacent non-protected areas. Whereas MPAs can increase biomass and species diversity within their boundaries, any effect on recruitment has yet to be observed. Knowledge of recruitment patterns deriving from MPAs could help determine their effectiveness as a fishery management tool. We obtained and analyzed 123 mtDNA control region sequences (420 bp) of juvenile kelp bass, *Paralabrax clathratus*, recruiting near two MPAs to establish the genetic makeup of the recruitment pulses. If an MPA was enhancing recruitment to adjacent areas, one might expect to see recruitment pulses dominated by groups of siblings and half-siblings spawned from one to few females in the area, possibly signaling locally derived recruitment. Sibling-dominated recruitment would potentially be indicated by a significant drop in the proportion of singleton haplotypes relative to an adult sample. Homogeneity tests for singleton counts among three separate sets of recruiting juveniles, versus adults, found no significant reductions, indicating that *P. clathratus* juveniles probably recruit in genetically well-mixed groups instead of sibling-dominated ones. The results do not support suggestions that MPAs significantly enhance adjacent areas through recruitment.

29 BEHAVIORAL RESPONSES OF SCALLOPED HAMMERHEAD SHARKS, *SPHYRNA LEWINI*, AND LEOPARD SHARKS, *TRIAKIS SEMIFASCIATA*, TO PULSED, DIRECT CURRENT ELECTRICAL FIELDS

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Electrical shark deterrents might be a less harmful way to protect people and equipment than meshing beaches or fishing for sharks. The use of strong electrical fields as a shark deterrent has shown promise, but has been poorly documented. Behavioral responses of sharks to pulsed, direct current electrical fields were quantified in the laboratory. Scalloped hammerhead sharks (SH) and leopard sharks (LS) were baited to an odor source when an electrical field was both off and on. A head twitch behavior was elicited in SH and LS at average voltage gradient thresholds of 4.16 ± 0.59 SD V/m and 4.30 ± 0.78 SD V/m, respectively. A shimmy behavior was elicited in some SH at an average threshold of 5.54 ± 1.55 SD V/m. A retreat behavior was elicited in SH and LS at an average, maximum threshold of 18.50 ± 13.27 SD V/m and 9.64 ± 10.28 SD V/m, respectively, which was indicative of the effective deterrent threshold and was higher than previously reported. Both SH and LS remained significantly farther away and spent significantly less time near the odor source when the electrical field was on than when the electrical field was off, although the sharks' responses were highly variable.

30 PHYLOGENY AND BIOGEOGRAPHY OF THE SERANNID FISH GENUS *EPINEPHELUS*

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The genus *Epinephelus* is comprised of 99 species of perciform fishes commonly known as groupers. This large and diverse group of fishes is distributed in tropical and sub-tropical waters worldwide. Although being recognized in the taxonomic literature for more than 200 years, recent molecular evidence suggests that this genus is paraphyletic and in need of revision (Craig, et al. 2001). Mitochondrial DNA sequences for 83 species of epinepheline serranids were gathered to determine phylogenetic relationships within *Epinephelus* and allied genera. The data confirm that *Epinephelus* is indeed a paraphyletic genus. Biogeographic interpretations of this data suggest that the new world may be the location of origination of many clades within this diverse group, and that the main radiation of many grouper lineages may have taken place during the miocene.

31 FISH SPECIES COMPOSITION FROM THE SEAFOOD MARKET OF ENSENADA, BAJA CALIFORNIA, MEXICO (2000–2001)

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From October 2000 to September 2001 we study the specific composition of commercialized fish species in the Seafood Market of Ensenada, Baja California, Mexico. Our objectives were to determine the fish species, the number of individuals, the monthly variation and the size of the fishes. A total of 106 fishstands were sampled, and were counted 7,928 individuals with a total biomass of 6,702 Kg. A number of 54 species belonging to 47 genera and 26 families were identified. The families represented by greatest number of species were Sciaenidae (nine), Serranidae (four), y Labridae (three). The monthly fish species varied from 13 (during the months of December, March and September) and 27 (during the month of July). According to relative abundance of commercialized individuals during the study, three groups of species were conformed, which five species and one family represented more of 5% of the samples, 13 species represented between the 1 and 5% and 33 less of 1%. The most abundant fish species commercialized during the period of study were: *Caulolatilus princeps* (21%), *Paralabrax nebulifer* (10%), *Amphistichus argenteus* (7%), the family Scorpaenidae (6.2%), *Paralabrax auroguttatus* (6%) y *Mugil cephalus* (6%). The species *C. princeps, Seriola lalandi, Roncador stearnsii* and *Menticirrhus undulatus,* contributed with the 56,4% of the total biomass. For each one of the species with more of 5% in the samples, we present information of the commercialized sizes. Do not exist regulation that establish minimum statures of capture for the fish species, except *M. cephalus,* which was commercialized during the period of study below their minimum stature of capture.

32 POLYCHAETOUS ANNELID ASSEMBLAGES ASSOCIATED WITH SEDIMENTS NEAR SEVEN SHALLOW WASTEWATER OUTFALLS ALONG THE TIJUANA-ENSENADA COSTAL CORRIDOR IN NORTHERN BAJA CALIFORNIA, MEXICO

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In July 2001, 21 benthic stations were sampled at depths between 5 and 13m, ranging from Tijuana to Punta Banda, Baja California, México. The aim of this study was to describe the species distribution and structure of the polychaete communities associated with soft bottom habitats that occur near seven known point sources of wastewater discharge in the region. A total of 1,637 polychaetous annelids representing 31 families and 84 species were identified, which constituted 60% of all macrofauna sampled. Most abundant families were Spionidae, Oweniidae, Cossuridae, and Ampharetidae, which accounted for 64% of the total polychaete fauna. Families with highest species richness were Spionidae, Cirratulidae, Lumbrineridae, and Terebellidae. The seven most abundant species were *Owenia fusiformis, Cossura* sp A, *Polydora cirrosa, Ampharete labrops, Spiophanes bombyx, Mediomastus* spp., and *Armandia brevis,* representing 63% of all polychaetes. *Nephtys caecoides* and *Spiophanes duplex* occurred at most stations, but were not abundant. Patterns of polychaete abundance and diversity varied from north to south. The area from Tijuana to Punta Descanso (north zone) supported lower numbers of polychaetes and lower diversity (H′), than the south zone between El Sauzal to Punta Banda. Six species described as opportunistic were located in the south zone, including *Capitella capitata, Cossura* sp, *Dorvillea annulata, Armandia brevis, Polydora cirrosa,* and *Notomastus tenuis.* Classification and ordination analysis based on species composition and abundance data recognized three distinct assemblages of stations within the southern zone. PCA analysis applied to environmental parameters resulted in three station groups defined by sediment grain size, and total organic carbon.

33 POPULATION SYSTEMATICS OF THE CAROLINA ANOLE, *ANOLIS CAROLINENSIS* VOIGT (IGUANIDAE: POLYCHROTINAE): GEOGRAPHIC VARIATION IN MORPHOLOGY

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The Carolina or green anole, *Anolis carolinensis,* has an extensive range throughout the Coastal Plain and contiguous regions of the southeastern United States. A considerable amount of morphological variation has been reported for this species but has never been fully quantified. In order to study the population systematics of *A. carolinensis,* we gathered a data set of 22 morphometric and meristic characters from 685 preserved specimens. Males and females from the study populations were separated into 17 locality-based, operational taxonomic units (OTUs) spanning the range of the species. OTU identification and selection were based on specimen availability, possible physiographic distribution barriers, and geographic variation in other regional herpetofauna. Specimens of *A. porcatus* from Florida and Cuba were selected as an outgroup in a cluster analysis of the data using the neighbor-joining method. The results of this study reveal distinct morphological differences between mainland populations of *A. carolinensis* and populations from peninsular Florida, with a possible line of demarcation at or near Alachua County, Florida. While previous studies have indicated a genetically distinct population in southwestern Florida, we recommend that taxonomic separation of the entire peninsula be withheld at this time, pending further study.

34 SALT TOLERANCE AND REMEDIATION POTENTIAL OF *SALIX LASIOLEPIS*: A NATIVE CALIFORNIA WILLOW

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Urbanization and agricultural practices have increased salinity levels in many S. California rivers/streams. Increased salinity levels may limit the success of trees commonly used to remediate degraded wetlands and riparian areas. We are therefore studying the salinity tolerance of several native S. California willows including *Salix lasiolepis* (Arroyo willow). In addition, given *S. lasiolepis*' phenotypic plasticity, we are studying salinity tolerance of *S. lasiolepis* from three different locations to identify populations with higher salinity tolerance. First we conducted small pilot studies of the salinity tolerance of asexually propagated *S. lasiolepis* cuttings grown in soilless medium under greenhouse conditions. Salt content of the medium was altered using dilute solutions containing 0, 50, 100, and 200 mM NaCl. At 9 weeks, differences in new growth weight among sites were observed. Mean new growth weight of control cuttings ranged from 0.12 to 0.24g depending on the population. Overall, mean new growth for each population decreased with increasing NaCl concentrations. However, new roots were not as negatively affected as new shoots and leaves were. Moreover, for two *Salix lasiolepis* populations, mean root dry weight of cuttings exposed to 100 mM NaCl was within 10% of their respective controls (109% and 96%). This preliminary study suggests that specific populations of Arroyo willow may be better suited for revegetation of riparian sites. It also suggests that salt tolerance of *Salix lasiolepis* may be enhanced with NaCl pretreatment. In the next phase of our study, cuttings from three populations will be pretreated with NaCl and then exposed to 0, 50, and 100 mM NaCl.

35 NORTHERN ORANGE COUNTY FALL 2001 WEATHER SUMMARY

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This poster displays the fall 2001 maximum and minimum daily air temperatures and the monthly average maximum air temperatures recorded at Yorba Linda, California, for the years 1988 through 2001. Also shown are the fall 2001 monthly surface and 500 millibar pressure maps for the northern hemisphere.

During October 2001, Yorba Linda recorded the third lowest monthly average maximum air temperature, while November 2001 had the second lowest average since the La Nina year of 1988. The fall started off with the formation of a 500 mb ridge pattern over the western portion of the United States and this ridge was later replaced by a trough system in the month of November and December. The presence of an upper level trough system allowed a series of surface storms to pass through southern California and caused the lower air temperatures. Generally, La Nina and El Nino events have an impact on west coast weather which will be described in the poster presentation.

36 TROPHIC LEVELS AND HEAVY METAL CONCENTRATIONS OF TERNS AT TWO CALIFORNIA NESTING COLONIES

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We determined the stable carbon and nitrogen isotope values and heavy metal concentrations for Caspian Tern (*Sterna caspia*), Elegant Tern (*Sterna elegans*) and Forster's Tern (*Sterna forsteri*) and their fish prey at the Bolsa Chica Ecological Reserve in southern California and, except for Elegant Tern, in south San Francisco Bay during the 1997–1999 breeding seasons. *^{13}C and *^{15}N values and concentrations of a wide variety of metals were obtained for abandoned eggs and livers of dead chicks of these tern species and for several prey species. In this presentation, we focus on a comparison of Cu (copper), Zn (zinc), Hg (mercury) and Cd (cadmium) concentrations in eggs vs. livers and on the relationship between Hg level and *^{15}N value within and among tern species. A significant increase (t-test) in the concentrations of Cu and Zn from eggs to livers was observed inmost cases for the tern species at both sites. Conversely, Hg levels, with one exception, were significantly higher (t-test) in the eggs than in the livers. The small range of *^{15}N values indicates that the birds feed on virtually the same trophic level and, thus, Hg biomagnification was not apparent. Cd concentrations were essentially at detection limits for all samples analyzed indicating limited bioavailability. Our results show marked differences in the concentrations of the four metals in eggs and livers, which appear to reflect not only differences in their bioavailability at the two sites but also in their requirements for physiological processes.

37 *ACANTHOCHONDRIA* SP. A, A NEW SPECIES OF PARASITIC COPEPOD (POECILOSTOMATOIDA: CHONDRACANTHIDAE) ON THE CALIFORNIA HALIBUT, *PARALICHTHYS CALIFORNICUS*, FROM SANTA MONICA BAY, CALIFORNIA

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A new species of parasitic copepod, *Acanthochondria* sp. A, is described from the California halibut, *Paralichthys californicus* (Ayers), collected from Santa Monica Bay, California. A total of 7 nonovigerous and 22 ovigerous females (each carrying a male) was collected from the gill cavity of the California halibut. This species of parasitic copepod can be distinguished from other species of *Acanthochondria* by the large body size, long posterior processes, and the structure of the legs. This is a relatively large copepod (almost 7.0 mm in length) and the posterior processes are much longer than those of other species of this genus. Legs 1 and 2 have relatively long rami with the endopod noticeably longer than the exopod. This species exhibits the characteristic sexual dimorphism of this genus, with the female (approximately 7.0 mm) noticeably larger and morphologically distinct from the male (less than 1.0 mm).

38 PARASITE-MEDIATED SEXUAL SELECTION OF GREEN SWORDTAILS, *XIPHOPHORUS HELLERI*

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Hamilton and Zuk (1982) introduced the concept of parasite-mediated sexual selection using the "good gene" theory, proposing that females preferred males with more pronounced secondary sexual characteristics because they were indicators of physically fit males possessing parasite-resistant genes. The contagion indicator hypothesis (Able 1996) branched from the "good gene" theory suggesting that females preferred non-parasitized males due to direct benefits of avoiding parasite contraction from courting males. Conflicting support and rejection of these theories have caused researchers to question their validity. Moller (1990) proposed that there might be flaws in previous researchers' methodology. Past researchers have used macroparasites as a measurement of an organism's fitness level without taking into account that they might be benign to the host's fitness, as well as unintentionally ignoring the effects of the microparasites that may also simultaneously inhabit the host. An immune analysis following an immune initiation would allow for an actual quantification of male fitness (Moller 1999). The intent of this study is to perform immune analyses via white blood cell counts from the peripheral blood and spleen of Green Swordtails, *Xiphophorus helleri,* following an immune initiation, along with parasite level counts of *Dactylogyrus intermedius* as a means of measuring male fitness. These techniques in addition to courtship studies will be used to determine if (1) non-parasitized males are in fact out competing parasitized males, (2) if immune analyses are better methods of quantifying a male's fitness level than parasite counts, and (3) if parasitism is a driving force for sexual selection.

39 THE BENTHIC COMMUNITY OF SAN DIEGO BAY

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Benthic infauna and sediment samples were collected at 46 stations in San Diego Bay, California as part of the coastal ecology component of the Southern California Bight 1998 Regional Monitoring Survey (Bight '98). All stations were selected randomly using the USEPA probability-based EMAP design and ranged in depth from 3 to 15.6 m. Infaunal community structure was summarized for each station and then compared to various environmental and sediment parameters (e.g., depth, % fines, total organic carbon, nitrogen, and several contaminants of concern). Ordination and classification analyses were also performed to examine the overall similarity of benthic assemblages in the bay. A total of 38,187 macrobenthic organisms representing 341 taxa were identified. More than 27% of these represented rare or unidentifiable taxa that occurred only once. Two species of polychaetes, the capitellid *Mediomastus* sp (likely a species complex) and the spionid *Prionospio* (*Prionospio*) *heterobranchiata,* were collected at all 46 stations. *Mediomastus* sp was also the numerically dominant taxon, comprising 13% of all organisms collected (n = 4,978 individuals). An introduced bivalve, *Musculista senhousia,* was the second most abundant taxon (n = 3,931 individuals), followed by the sabellid polychaete *Euchone limnicola* (n = 3,894 individuals). Preliminary analyses suggest that tidal flushing may be the primary factor influencing the distribution of benthic assemblages or sub-assemblages throughout the bay. This survey provides valuable baseline data against which future changes in the ecology of the subtidal benthos of San Diego Bay may be assessed.

40 PROBABLE LATERITE IN THE PALEOCENE LAS VIRGENES SANDSTONE, SOLSTICE CANYON, SANTA MONICA MOUNTAINS, CALIFORNIA

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A nine-meter thick Paleocene paleosol present in the Las Virgenes Sandstone, Santa Monica Mountains, California, probably represents an ancient soil formed in a tropical climate. The paleosol is interbedded with sandstones and mudstones deposited in a fluvial environment. Four zones occur in the paleosol. The lowermost Zone 1 is a reddish fining upward sequence of weathered sandstone (60% quartz, 20% feldspar, and 20% kaolinite) and mudstone. Zone 2 is mottled white and purple and consists of 70% quartz and 30% kaolinite. Iron pisolites in a matrix of 25% quartz and 75% kaolinite comprise Zone 3. The uppermost Zone 4 consists of iron pisolites in a matrix of 15% quartz and 85% kaolinite. Sandstones above and below the paleosol contain 60% quartz, 25% feldspar, and 15% kaolinite and are compositionally similar to Zone 1, indicating the paleosol formed on sandstones. The upward decrease in quartz, loss of feldspar and increase in kaolinite results from feldspar alteration to kaolinite and to quartz dissolution as the paleosol formed. Iron pisolites resulted from iron accumulation as iron minerals were leached. Zones identified in the paleosol are similar to those of lateritic soils that develop mostly in tropical climates.

41 ASSESSMENT OF THE HEALTH OF KELP HABITATS ALONG THE NORTH COAST OF SANTA MONICA BAY

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The distribution and abundance of kelp forests flanking Santa Monica Bay are spatially and temporally patchy, especially along Malibu, and have shown a decline over the past 20 years. To assess the health of kelp habitats, a suite of physical and chemical factors were investigated in Malibu to determine their influence on kelp distribution and abundance. These factors were also measured in Palos Verdes (PV), an area where kelp abundance has remained relatively high. Surveys showed that adult kelp abundance was similar in Malibu and PV presumably because we chose patches where kelp was abundant. However, sub-adult (< 1m) and juvenile kelp abundance was higher in Malibu than PV suggesting a higher early survivorship. These results also suggest that Malibu kelp beds were not recruitment limited. The availability of hard rock surfaces was found to be higher in PV. In contrast, Malibu substrate was composed of mostly sediment, including areas >10 cm deep. Sediment particle size analysis suggested that sediment in Malibu was composed of more clay and silt than PV sediment, which was mostly composed of sand. The smaller grain size in clay and silt are more easily transported and re-suspended into the water column. The clay and silt content also suggest a terrestrial influence in Malibu, which was supported by a higher content of organic matter in Malibu sediment. The amount and stability of suitable substrate and the sediment type appeared to have the largest influence on kelp distribution and abundance in Malibu and may help explain the patterns that have been observed over the past 20 years.

42 SOIL MICROBIAL ACTIVITY AND MYCORRHIZAL ASSOCIATIONS IN A SOUTHERN CALIFORNIAN SALT MARSH

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Traditionally, wetland restoration projects have focused on restoring the natural vegetation and hydrology of the ecosystem. However, often overlooked are the subsurface soil components of the

system that are crucial to nutrient cycling, as well as the degradation of toxic compounds. In this project, we evaluated the spatial and temporal dynamics of the soil microbial community in the natural salt marsh and restored sites at Mugu Lagoon, Ventura County, USA.

We used two different indices, one specific and one general, to assess the overall soil microbial community. The first method used was soil respiration—the rate of CO_2 efflux from the soil. While soil respiration is a rather general indicator, it provides a valuable overall measurement of the soil's biological activity. Measurements of soil respiration were conducted using a closed, dynamic-system infrared gas analyzer. The second method used to assess the microbial community was mycorrhizal associations. The symbiotic infection of plants by arbuscular mycorrhiza has been shown to commonly occur in terrestrial plants but is less well understood in aquatic environments. By understanding the distribution of, and factors affecting mycorrhizal associations, restoration efforts can potentially facilitate the symbiosis, and promote a more active soil microbial community.

43 OCCURRENCE OF *GYRODACTYLUS PERFORATUS* (MONOGENEA) ON ITS FISH HOST *CLEVELANDIA IOS* (GOBIIDAE) FROM BODEGA BAY AND TOMALES BAY, CALIFORNIA

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The monogenetic trematode *Gyrodactylus perforatus* was previously reported to infect populations of the arrow goby, *Clevelandia ios,* from Bodega Bay, California. *Clevelandia ios* were sampled from Bodega Bay and nearby Tomales Bay using two different collection methods and examined for *G. perforatus.* Procedures for removal, processing and examination were previously developed for microscopic monogenes in other fish hosts and these processes were adapted for this study as necessary. *Gyrodactylus perforatus* was found on hosts in Tomales Bay, thus extending its range beyond its type locality, Bodega Bay. Parasitism by *G. perforatus* on *C. ios* was statistically significant between the samples and higher in Bodega Bay.

44 MANAGEMENT OF THE CALIFORNIA LEAST TERN BREEDING POPULATION

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The California Least Tern (*Sterna antillarum browni*) breeds from April through August at nesting areas along the coast from the San Francisco Bay, California to lower Baja California, Mexico. Prior to its listing as endangered under both the federal and California Endangered Species Act in the early 1970's, the progressive conversion of suitable nesting habitat to human uses had resulted in a severe reduction in both nesting sites and numbers of nesting pairs. Thereafter, the number of nesting pairs in California escalated from an estimated 664 in 1976 to over 4,000 in 2001, and up to 38 nesting sites are now used, up from 23 in 1976, when statewide censuses were initiated. However, over 80% of the nesting population is concentrated in 10 sites. In addition, poor production years such as 1999 still threaten the population, as does predation by a variety of both native and non-native predators. However, predator management at some sites seriously threatens other uncommon native species. Thus, although continued predator management will be required to ensure the health of the Least Tern breeding population, the upcoming revised Recovery Plan must include a comprehensive and enforceable predator management plan that considers the needs of predators that have a relatively minor effect on Least Tern reproductive success.

45 CONSERVATION OF THE ENDANGERED SOUTHERN CALIFORNIA STEELHEAD IN THE VENTURA RIVER: AN UPDATE ON THE PROPOSED REMOVAL OF MATILIJA DAM

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In 1997, the National Marine Fisheries Service added the Southern California Steelhead (*Oncorhynchus mykiss*) to the endangered species list. It is estimated that annual steelhead runs in southern

California streams declined from 55,000 to less than 500 returning adults in the past half century. Historic runs in the Ventura River, considered a source population for smaller coastal streams, are estimated at over 5000 fish. Barriers to passage are one of the leading causes of steelhead decline in southern California. In the Ventura River system, Matilija Dam is the largest fish passage barrier, blocking access to the majority of historic spawning and rearing habitat in Matilija Creek. The dam was constructed in 1947 to control flooding of the Ventura River, and provide storage for a municipal water supply. However, given the highly erodable geology of Matilija Canyon, the reservoir quickly filled with silt, estimated today at around 6 million cubic yards of material. Currently, the dam provides no flood control, and very little storage. Removal of the dam would double the amount of spawning and rearing habitat in the Ventura River system. In 1998 the Ventura County Board of Supervisors committed to dam removal. The Matilija Dam Ecosystem Restoration Feasibility Study, a joint project of the U.S. Army Corps of Engineers and the Ventura County Flood Control District, is currently underway. Preliminary results of the study and the development of a habitat evaluation protocol for assessing the impact of dam removal will be discussed.

46 CONSERVATION DILEMMAS INVOLVING ENDANGERED SPECIES IN THREE SOUTHERN CALIFORNIA HABITATS: SAN MIGUEL ISLAND, BOLSA CHICA WETLANDS AND RIPARIAN WOODLANDS

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Protection of endangered species often leads to policies that may cause problems for other species, or require habitat manipulation. Three examples of this are presented. Reintroduction of bald eagles to the northern Channel Islands may harm alcids. Restoration of the Bolsa Chica wetlands for light-footed clapper rails will harm Belding's savannah sparrow, another endangered species. Finally, artificial destruction of flood protected riparian woodlands, a policy generally not favored, may be necessary to maintain habitat for least Bell's vireo.

47 THE IMPORTANCE OF MANAGEMENT OF THE NATIVE PARASITIC PLANT *CUSCUTA SALINA* IN SOUTHERN CALIFORNIA SALT MARSH HABITAT

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The disappearing coastal salt marsh habitat of California has a small number of native, specialized plant species, which include a native plant parasite, alkali dodder (*Cuscuta salina*). Though little is known about the ecology of parasitic plants, there is evidence of coevolutionary interaction between *C. salina* and plants in the Pickleweed (*Salicornia virginica*) series which may influence the boundaries of plant communities and their diversity. Historically, *Salicornia* has been known for its agricultural uses and it is the nesting area for endangered bird species. Research has also begun into the pharmacological uses of *Cuscuta*. Both for the ecological and economic benefits, it may be preferable to manage rather than eradicate this parasitic plant in its native habitat.

48 AVIAN POPULATIONS IN DIMINISHING OPEN SPACE: A SURVEY OF THE BIRDS OF SIGNAL HILL, CA

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It is the nature of environments to change. Entire epochs of our earth's history are marked by massive, and sometimes devastating, environmental changes. Modern society often brings about rapid change, and the urbanization of our landscape has caused sometimes-drastic changes in the make-up of avian populations. Even small pockets of open space and natural plant communities can harbor and maintain a high diversity of bird species. This study was designed to monitor and record the changes in the open space remaining on Signal Hill, California. Since September of 2000, biweekly avian surveys have been conducted at prescribed points, with opportunistic observations made in between. I found 23 permanent resident species, 5 winter residents and 28 transient species, of which 40% use the area as they pass through on migration or as temporary hunting grounds. The winter resident Yellow-rumped Warblers are particularly abundant, comprising up to 75% of the entire avian population during the winter months. Excluding transients, populations sizes of most of the species remained largely the same during the study period. Loggerhead Shrikes (*Lanius ludovicianus*) and Say's Phoebes (*Sayornis saya*), however, have both shown substantial decreases during the study, and their extirpation from the area may be imminent. This is concurrent with the ongoing transition of open habitat to housing tracts. These data will serve as a base line for further studies as urbanization of the area continues.

49 ARE SOUTHERN CALIFORNIA'S CHANGING COASTAL WATERS AND NEARSHORE BIOLOGICAL COMMUNITIES BECOMING MORE SUSCEPTIBLE TO INVASION BY EXOTIC SEAWEEDS?

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Evidence suggests that invasive species may impose increasing threats to biodiversity because of global change. For example, increased sea temperatures can alter the distributions of marine species, and make northern regions more susceptible to invasions by species native to lower latitudes. Southern California's waters experienced a two-decadal warming period beginning in the mid-1970s, and recently appear to have entered a cooler thermal regime. These urban coastal ecosystems also were exposed to increasing levels of urban run-off and other forms of anthropogenic disturbance. During this period changes have occurred in the composition of coastal seaweed communities. Until recently, few introductions of exotic seaweeds have been reported in Southern California. Perhaps, seaweed invaders escaped detection because of their small size or identification difficulties. During the last five years, however, three conspicuous seaweeds invaded Southern California waters. *Undaria pinnatifida,* a kelp native to the western Pacific was recently reported in Los Angeles, Port Hueneme, Santa Barbara, and Monterey harbors, and off Santa Catalina Island. *Caulacanthus ustulatus,* a small, red alga, has been found in rocky intertidal habitats along the Orange County coast where it grows as a low turf. Lastly, *Caulerpa taxifolia,* first noted as an invader in the Mediterranean Sea, was found in Agua Hedionda Lagoon in San Diego County and Huntington Harbour in Orange County. The appearance of these seaweeds may be related to changing ocean conditions, but nevertheless represents a warning that other exotic species might be capable of establishing populations in changing Southern California waters.

50 WHAT IS NONINDIGENOUS AND IS IT ALL BAD?

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The present symposium and numerous publications document the negative ecological impacts and economic costs associated with the numerous nonindigenous forms of many taxa that have been introduced around the world. The normally accepted definition of nonindigenous is anything that is not found naturally in a particular geographic location. We discuss this definition critically, using a diverse array of examples. Nonindigenous forms run the gamut from genes to species, involving intergradation, introgression and competitive replacement. Introduction scales for aquatic forms range from intrabasin to intercontinental. Origins may be "natural" or anthropogenic including both intentionally and nonintentionally translocated forms. Time frames range from prehistoric to recent. We speculate briefly on some questions of value and ethics, including our view of the reasons we consider nonindigenous forms negatively. We conclude that all biological entities introduced into an area by man's activities should be considered nonindigenous, but that all are not equal, either ethically or practically. When considered holistically the presence of some nonindigenous forms may be beneficial.

51 THE MARINE INVADERS OF CALIFORNIA: LESSONS FROM SAN FRANCISCO AND SAN DIEGO

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Invasions of exotic species continue to alter the structure and functioning of ecosystems worldwide, and the coastal embayments of California now harbor a wide variety of introduced plants and animals.

While San Francisco Bay has a well-deserved reputation as one of the most invaded ecosystems in the world, the coastal systems of San Diego also have many invaders. Although any comparisons across these systems must be viewed as preliminary because of uneven sampling effort, examination of invaders in these two systems reveals some interesting patterns. These include an increasing rate of appearance of exotics in recent decades and unique suites of invaders that highlight differences between the two regions. Detailed examination of two California invaders, the salt-marsh destroying isopod *Sphaeroma quoyanum* and the mat-forming mussel *Musculista senhousia* highlights two broad issues that merit increased attention in invasion biology: 1) the existence of prolonged lags between the initial invasion and subsequent population explosion of exotics, and 2) the ability of exotics to profoundly affect invaded ecosystems by altering the physical nature of habitats through ecosystem engineering.

52 U.S. RESPONSE TO POTENTIAL ECOLOGICAL THREAT TO SOUTHERN CALIFORNIA ECOSYSTEMS BY THE INTRODUCED MARINE CHLOROPHYTE *CAULERPA TAXIFOLIA*

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In 2000, the invasive strain of the seaweed *Caulerpa taxifolia* was documented at two southern California sites. A clone of this strain inadvertently introduced into the Mediterranean in the 1980's is reported to currently blanket over 13,000h of bottom, often to the exclusion of native seaweeds, seagrasses, reefs, and other communities. Upon discovery of this species in the U.S., regulators had to quickly assess the potential threat of this introduction and develop an appropriate response. Despite conflicting evidence on the ecological impact of this strain, the majority of reports from the Mediterranean suggested that delay could be fatal to a successful eradication effort, a conclusion that had already prompted the addition of *Caulerpa taxifolia* to the Federal weed lists and the development of a national response plan prior to its discovery. Scientists and government agents concluded that due to *Caulerpa*'s rapid growth potential, ecological plasticity, and toxic qualities, these infestations had to be treated immediately. No long term monitoring was conducted prior to initiation of eradication efforts in California, however review of distribution maps of eelgrass before the infestation seems to confirm its reported tendency to displace native habitats. Due to American hesitancy regarding field research on extant *Caulerpa,* future empirical assessments of its ecological impacts will likely be designed as collaborations among affected countries, such as Australia, France, Italy, where eradication is not being pursued. Likely impacts of *Caulerpa* on our ecosystems include competition with native species, interruption of floral and faunal recruitment, and general alteration of existing habitats.

53 EXOTIC AQUATIC TURTLES ON THE WEST COAST: CONSIDERATIONS AND IMPLICATIONS

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In the states of California, Oregon, and Washington, at least 27 species of exotic (non-native) aquatic or semi-aquatic turtles from 20 genera and 5 different families have been recovered or reliably reported from within the range of 3 native aquatic turtle species: the western pond turtle (*Clemmys marmorata*), the western painted turtle (*Chrysemys picta*), and the Sonoran mud turtle (*Kinosternon sonoriense*). Many of these turtles originated as pets or as potential food sources for human consumption. At least 4 of these exotic species are known to be reproductively established in one or more locations in the wild, and another 2–3 species have a high potential of becoming reproductively established as well. Concerns regarding the establishment of exotic turtles in the wild include potential negative impacts to native turtles and other wildlife species through the transmission of pathogens and/or parasites, direct and indirect competition, and predation. We discuss the exotic turtles most liable to cause harm to the native turtle fauna and possible measures to control or reduce the spread of exotics.

54 EXOTIC FISH SPECIES AND THEIR IMPACTS ON SMALL COASTAL LAGOONS IN SOUTHERN CALIFORNIA

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Both freshwater and estuarine exotic (non-native) fish species impact small souther California coastal lagoons. In the seven small lagoons (0.5–50 hectares) on Marine Corps Base Camp Pendleton, the larger of these lagoons are more impacted by exotics because they have larger drainages upstream that support freshwater exotic, primarily mosquitofish, sunfishes and black basses, and catfishes. The smaller of these lagoons have fewer upstream sources and more seasonal drying upstream that impede downstream movement by exotics. Marine invasion has been documented for two exotic species, yellowfin goby and striped bass, both particularly facilitated by the latest El Nino-La Nina cycle. The El Nino coincided with a large increase in yellowfin goby recruitment in the Santa Margarita estuary and the only occurrence of this goby in several smaller systems. Increased numbers of striped bass arrived later during the following La Nina. There appears to be a strong negative correlation of mosquitofish with tidewater goby success at some sites. The federally endangered tidewater goby appears to do best in the smallest sites without mosquitofish. The striped bass were few in number and apparently had little impact and the increase of yellowfin gobies was relatively short lived, as the influx of other southern native forms, that their effect was relatively fleeting.

55 INVADER IN THE OPEN SEA! THE NEW ZEALAND MARINE *SNAIL PHILINE AURIFORMIS* IN SOUTHERN CALIFORNIA COASTAL WATERS

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Sometime in late 1994 *Philine auriformis,* a clam predator from New Zealand, first appeared in Southern California Bight (SCB) coastal waters. This is one of a few documented introductions to shelf communities; most exotic species are reported from bays, harbors, or the intertidal zone. *P. auriformis* was first collected in California from San Francisco Bay in 1993, and spread within a year to Bodega Bay to the north. By the spring of 1995 specimens were abundant on the shelf off Los Angeles and of very large size. Population density increased in 1995 and 1996 only to decline in 1997 and 1998. Off San Diego the population cycle was similar but less pronounced. By 1998 the species was established at reduced density in much of the Bight based on regional monitoring. Such coastal invasions may pass unnoticed in transitional areas such as the SCB because of high natural variability. Predator/prey interactions with other animals are discussed in relation to the invasion history.

56 INTERACTION BETWEEN NATIVE FISH, HABITAT, AND EXOTIC FISH SPECIES IN THE MIDDLE SANTA ANA RIVER, SOUTHERN CALIFORNIA

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Two native fish species, Santa Ana sucker and arroyo chub, occur in about 55 km of the middle Santa Ana River. The upstream 9 km with higher gradient, rocky and gravelly, substrate, and artificially fluctuating flow supports populations of each species. The stream adapted sucker and chub are maintaining themselves in artificially fluctuating flows that probably limit most of the egg-laying exotics fishes. Two exotics, the live-bearing mosquitofish and mouth-brooding tilapia can survive. The next river reach down to Prado Dam (27 km) with lower gradient, overwhelmingly shifting sand substrate, increased turbidity, and dampened fluctuation in flow, lacks arroyo chubs. Juvenile suckers occur in small numbers in spring, summer and fall, after the spring spawning season upstream and adult suckers are rare. Exotics like mosquitofish, sunfishes and largemouth bass, carp, and bullhead catfishes are common. The lowermost reach below Prado Dam (19 km) with higher flows, more turbidity, and a mixture of substrates, has only a few adult suckers and no arroyo chubs. Exotics are more common including channel catfishes. Arroyo chubs, ecologically more adapted to the lower gradients, are absent downstsream apparently because of the high number of predatory exotics. Sucker reproduction is lacking downstream or not successful. During the El Nino spring of 1998 juvenile suckers were common below Prado Dam indicating possible reproduction at that time. Channel catfishes were rare. In later years channel catfishes greatly increased in numbers and both adult and small suckers were very rare. High flows appear to have improved conditions for suckers in 1998.

57 MONITORING OF NEARSHORE MARINE HABITATS FOLLOWING BEACH REPLENISHMENT ACTIVITIES

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The San Diego Regional Beach Sand Project dredged just over two million cubic yards of sand from four offshore borrow sites and replenished 12 beaches along the coast of San Diego County from Oceanside to Imperial Beach. Surveys conducted during the environmental documentation process identified nearshore rocky reefs in the vicinity of several of the proposed receiver sites. Concern from resource agencies and commercial fishermen regarding the potential for the sand placed on the beaches to impact these reefs promulgated monitoring of rocky intertidal, shallow subtidal, and kelp forest habitats in the vicinity of select receiver sites. The purposes of the monitoring are to determine any significant effects to sensitive marine resources, to understand the long-term ramifications of the project, and to aid in the design of future projects. Determination of monitoring locations and sample design will be discussed and preliminary data presented.

58 ANALYSIS OF AERIAL PHOTOGRAPHS TO DETERMINE THE EFFECTS OF THE DIABLO CANYON POWER PLANT THERMAL DISCHARGE ON KELP CANOPIES

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We analyzed aerial photographs taken in summer/fall of 1969–91 and 1997–98 to determine the effects of the Diablo Canyon Power Plant thermal discharge on the surface canopies of giant kelp, *Macrocystis,* and bull kelp, *Nereocystis.* During each survey, color IR transparencies (9@ × 9@) were taken sequentially (30–60% overlap) along a 14 km section of coastline. The images were digitized (1 m resolution) and the color bands representing kelp canopies were extracted using Adobe Photoshop_. GIS (ArcView_) was then used to geo-reference the kelp images to a projected USGS model of the coastline. Because bull kelp and giant kelp often appeared similar in the photographs, we also conducted ground-truth surveys to verify the locations of the two species. Kelp cover for various segments of the coastline were calculated using GIS, and the data were analyzed using a before-after-control-impact statistical design to test for changes in surface canopy cover in high and low impact areas, relative to controls. Bull kelp declined significantly in Diablo Cove after power plant start-up, and giant kelp gradually increased in the same habitats. Consequently, the main discharge effect was a shift in species composition, but not an overall change in summer/fall canopy cover. In contrast, total kelp cover significantly increased in the low impact area adjacent to Diablo Cove, mainly from increases in giant kelp. The photographs also provide a valuable long-term record of natural variation in kelp canopies related, in part, to regional influences from El Niño events and sea otter predation on herbivore populations.

59 INTERPRETING HISTORICAL RECORDS OF SIZES OF KELP BEDS

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Many of the 24 kelp (*Macrocystis*) beds of San Diego and Orange Counties appear to have been nutrient-limited during most of the past two decades, based on canopy histories as determined by aerial photography. Frequent occurrences of moderate-to-large el nino events since 1982 have undoubtedly been influential in maintaining a general nutritional deficiency in the local coastal waters. 1989–90 were exceptional years that witnessed a powerful la nina, associated with large expansions by most of these beds. A moderate la nina episode following the large 1997–98 El Nino was also beneficial for *Macrocystis* canopies, but not to the degree that occurred during 1989–90.

60 UPDATE ON THE SAN CLEMENTE ARTIFICIAL REEF PROGRAM

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The second year of monitoring the 22.4-acre San Clemente Kelp Experimental Artificial Reef (SCAR) has been completed. This study is directed by the California Coastal Commission, conducted mainly by the Marine Science Institute of the University of California Santa Barbara and San Diego State University, and funded by Southern California Edison. Two materials, broken concrete and quarry rock, and three bottom coverage densities, 17%, 34%, or 67%, are being tested to determine the best design for the build-out of this kelp mitigation reef to 150 acres. The experimental reef was built in September 1999. Results shows that the fifty six 40 m by 40 m concrete and quarry rock low-relief modules: 1) remain physically stable; 2) are maintaining kelp; and 3) have populations of fish, algae, and invertebrates that are comparable in density to nearby natural reefs, but differ in species composition. This program is also studying the potential effect of SCAR on the adjacent City and State Beaches. In the project's environmental review phase, concern was raised about the potential of reef material washing up on the beach, and kelp wrack increasing substantially. Routine observations of the San Clemente beaches show no artificial reef material, either quarry rock or concrete, has washed onto the beach, nor has there been evidence that kelp wrack from the artificial reef makes any significant contribution to the limited amount of seaweed wrack that has routinely appeared on the beach. It is likely that episodic large wave events drive the significant beach accumulation of kelp wrack. Nearshore conditions over the two years and since the reef was built have been somewhat tranquil, that is, without major storms. The program scientists are awaiting significant storms or an El Nino event to provide an effective test of the likelihood that the artificial reef will contribute significantly to wash-up of wrack or artificial reef material on local beaches and/or have other measurable or possibly catastrophic influences on SCAR.

61 REEF–A VOLUNTEER FISH MONITORING PROGRAM IN CALIFORNIA

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The REEF Fish Survey Project is a volunteer fish-monitoring program developed by the Reef Environmental Education Foundation (REEF). REEF volunteers collect marine fish distribution and abundance data using a standardized visual method during regular Scuba and skin diving activities. Survey data are recorded on preprinted data sheets that are returned to REEF and optically digitized. These data are housed in a database that is publicly accessible on REEF's Website (http://www.reef.org). Since its inception in 1993 the REEF program has generated over 35,000 surveys in the Caribbean region. In 1997 REEF expanded to the west coast of the United States and Canada, and to date, approximately 1,500 surveys have been conducted in California. REEF's standardized census method provides a consistency in data collection applied over a wide geographic range. The database establishes baseline data, provides a taxonomic inventory, and can be used to develop species distribution maps and examine species and community trends. Analyses of the California REEF dataset will be presented, including a species distribution and diversity atlas.

62 LONG-TERM CHANGES IN FISH POPULATIONS IN THE VICINITY OF DIABLO CANYON POWER PLANT, CENTRAL CALIFORNIA

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The Diablo Canyon Power Plant is a 2200 MW nuclear facility located midway along a 20 km (12 mi) reach of rocky coastline in central California. We studied the effects of heated seawater from the cooling water discharge on fish populations in Diablo Cove and surrounding areas by conducting visual censuses along permanent subtidal transects. Quarterly surveys began in 1976, nine years before plant start-up in 1985, and have continued through 2002. Over 80 fish species representing 30 families have been counted in 115 surveys. We used a BACI-type analysis to measure discharge effects on the common fish species by comparing temporal changes in their abundances between Diablo Cove and a nearby control area. Approximately 35% of the 37 taxa tested for power plant impacts increased after plant start-up, 20% decreased, and 15% were unchanged. Counts on the remaining 30% were too variable to yield conclusive test results. Bat rays, leopard sharks, white seabass, pile perch, señoritas, and kelp bass were among the species that were attracted in greater numbers to the shallow areas of Diablo Cove. Species with cool-temperate affinities, such as painted greenlings, kelp greenlings, and cabezon, were among the species that declined. The longevity of this study has enabled us to track natural changes in local fish populations related to large scale phenomena such as El Niño warming events, and also describe subtle long-term changes that continue to occur in Diablo Cove as a result of the thermal discharge.

63 DECLINES IN ROCKY REEF FISH POPULATIONS: HAVE DIFFERENT SPECIES RESPONDED SIMILARLY TO ENVIRONMENTAL CHANGE?

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There is compelling evidence that the abundances of many coastal species off southern California have undergone dramatic declines over the past two decades concurrent with declines in productivity. The decline in productivity represents a natural, large-scale perturbation and provides an opportunity to understand whether and how various components of coastal ecosystems respond. We conducted time-series analyses on long-term studies of non-exploited fish populations throughout the Southern California Bight to describe their temporal trends and explore the timing and magnitude of change. The species examined were classified as to trophic level, mode of reproduction and longevity, and habitat. In general, the magnitude of decline was similar for all species, regardless of classification. Trends were similar at all locations examined within the Bight, suggesting regional declines in abundances rather than redistribution of individuals. These patterns are consistent with the explanation that a regional decline in productivity is responsible for regional decline in fish stocks.

64 LONGTERM DECLINE OF ICHTHYOPLANKTON ABUNDANCE IN SANTA MONICA BAY

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From 1974 to the present, the Vantuna Research Group at Occidental College has monitored the ichthyoplankton of King Harbor, Redondo Beach. Ichthyoplankton tows have been conducted monthly during this period. This database enables us to infer the abundance of over 100 species of larval fishes during this period. Nearly every species has declined during this period. This decline mirrors a decline in plankton volume and is similar to trends observed for adult fishes. While this report is on the fish larvae of the nearshore environment, these declines are indicative of regional trends for the Southern California Bight.

65 REGIME SHIFTS IN CALIFORNIA CURRENT ZOOPLANKTON ASSEMBLAGES

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The CalCOFI zooplankton time series extends from 1949 to present, providing an unprecedented opportunity to assess long-term variability in North Pacific pelagic assemblages and the links of such variations to climatic forcing. Although El Niño-scale perturbations to pelagic assemblages have long been recognized, here we present evidence that lower frequency, multi-decadal scale variations occur. In addition to significant changes in 1977, corresponding to a widely recognized basin-scale Regime Shift, appreciable changes in absolute and relative abundance of various zooplankton taxa occurred in 1999. These latter changes have persisted much longer than is typical of La Niña, posing the question whether we have again entered an altered climatic regime in the NE Pacific. The relationship of these zooplankton shifts to variations in the Pacific Decadal Oscillation will also be discussed.

66 MONITORING SUBTIDAL COMMUNITY CHANGES AT SURVEY ROCK, ANACAPA ISLAND: FORTY YEARS AND STILL COUNTING

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In the early 1960s, Neushul *et al.* studied the distribution of organisms on the south side of East Anacapa Island, CA. Their 3-year study mapped the occurrences of common macroinvertebrate and kelp species from the lower limits of the intertidal down to a depth of 40 meters, recording dense populations of *Macrocystis pyrifera, Agarum fimbriatum* and *Pterygophora californica.* From 1981 to 2001, the Tatman Foundation's Channel Islands Research Program has returned annually to Neushul's site at Survey Rock to study the kelp bed and surrounding areas from 6 to18 meters in depth. Permanent transects and photo-quadrats were established in order to monitor the density and distribution of macroalgae, sea urchins, and other benthic invertebrates. Kelp and other macroalgae, once in great abundance, have been largely absent at the site since 1986 due, in part, to a combination of severe urchin overgrazing and El Niño episodes. Even during La Niña periods the macroalgae did not recover as expected. Our experimental studies at Survey Rock have also helped explain some of the less-obvious dynamics between urchins, macroalgae and sessile invertebrates. Since the early 1990s we have documented some unexpected and unprecedented trends, including vast increases in the abundance of the brittlestar *Ophiothrix spiculata* and related decreases in some sessile invertebrate species. We report on these trends and other changes in community structure at Anacapa Island supported by subtidal observations spanning a period of over 40 years.

67 THE NEARSHORE FISH ASSEMBLAGE OF THE SAN DIEGO/LA JOLLA ECOLOGICAL RESERVE

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Marine reserves such as the San Diego-La Jolla Ecological Reserve (SDLJER) are quickly becoming a primary tool in the management of coastal marine ecosystems in California. The San Diego-La Jolla Ecological Reserve was proposed in 1961 and established 10 years later. It has remained in place since that time and represents one of the few marine reserves in extreme southern California. Although relatively small (approximately 500 acres, including 1.6 miles of shoreline), it includes a variety of habitats such as a kelp forest, boulders of various sizes and steep canyon walls. Beginning in January, 2002, a repeatable, quantitative protocol was established to monitor conspicuous marine fishes within the SDLJER as a means of comparing abundance and diversity with comparable habitats that are currently not under protection. Preliminary data suggests that the SDJER may serve to protect fisheries target species and maintain upper size classes, and has a more diverse fish assemblage than that observed at unprotected reefs at nearby Pt. Loma.

68 REMOTE TRACKING OF GIANT SEA BASS (*STEREOLEPIS GIGAS*) USING AN ACOUSTIC SENSORY ARRAY AROUND ANACAPA ISLAND

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It is thought that giant sea bass form a spawning aggregation at Anacapa Island during summer months. Attempts to observe and document this event using traditional underwater monitoring and observation techniques have not been entirely successful. Difficult diving conditions and the mobility of the species create a very challenging situation that required a non-traditional approach. New acoustic telemetry technology allowed for a non-traditional means of gathering quantitative data. This project was the first to put Vemco VR2 remote logging hydrophones in the field. These hydrophones were set up in an array that completely encircles the island. This array allows for the nearly continuous detection of acoustic tagged giant sea bass that remain in the vicinity of the island. The array has allowed the collection of a dataset that provides information on habitat use, migration to and from

the island as well as movements around the island. To date we have tagged 27 adult giant sea bass at Anacapa Island and we are moving ahead with plans to expand the array to neighboring islands and begin data collection on some additional species.

69 SEXUAL DICHROMATISM AND SPAWNING BEHAVIOR OF THE KELP BASS, *PARALABRAX CLATHRATUS*, FROM SANTA CATALINA ISLAND, CALIFORNIA

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The kelp bass, *Paralabrax clathratus,* is a common nearshore reef fish of the Southern California Bight, being abundant on both the mainland and the Channel Islands. Although the biology of kelp bass has been well studied, aspects concerning its mating system and reproductive behavior have received little attention. The purpose of the study is to describe several aspects of the mating system including (1) seasonal sexual dichromatism, (2) spawning behavior, and (3) general mating strategies of breeding adults. Behavioral observations while on SCUBA were conducted along with underwater video to document and describe spawning behavior. Visual fish transects performed at two sites were used to assess the seasonal frequency of sexual dichromatism in adults. Data from samples collected via hook and line indicate that ripe males adopt a highly visible, orange snout coloration that is absent in ripe females, juveniles, and unripe adults. A separate tank study will be described in which hormonal injections were done to induce the coloration in adult males and validate it as a characteristic unique to breeding males. Gonadosomatic indices calculated from ripe adults collected during peak breeding season showed that adults may invest up to 12% of their body weight for gamete production, indicating the species as a group-spawner. Spawning rushes have been observed on several occasions and have consisted of 6–16 individuals. Spawning rushes have only been observed during twilight hours, although data from collected specimens show that eggs may become hydrated throughout the day.

70 REPRODUCTIVE BEHAVIOR AND MATING SYSTEM OF THE TEMPERATE WRASSE, *HALICHOERES SEMICINCTUS*

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The reproductive biology of the southern California labrid fishes has been studied extensively in the past and has led to further study of their behavior and ecology. The reproductive behavior and mating system of the rock wrasse (*Halichoeres semicinctus*) has been recorded and monitored in and around Big Fisherman's Cove, Santa Catalina Island, CA during April–October 2001. Three sites were visited almost daily during June–August and observed twice monthly during the spring and fall. It has been found that group spawning occurs with small (<20 cm), initial phase individuals with an average of 10 individuals per spawn. It appears that large, terminal phase males hold territories and participate in pair spawnings. Sex change in this species is rare (<5%) and a nearly 1:1 sex ratio has been shown. Abundances of rock wrasse fluctuated at the three sites throughout the day indicating that there was movement to and from spawning sites. All spawnings were seen between the hours of 800 and 1200, though aggressive, territorial behavior by terminal phase males was witnessed throughout the day. The majority of spawning occurred on the downcurrent edges of the studied rocky reefs.

71 PUTATIVE FUNCTION OF TYROSINE D OF PHOTOSYSTEM II PROBED BY FLUORESCENCE AND OPTICAL ABSORBANCE SPECTROSCOPY

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Photosystem II of the photosynthetic light reactions contains two redox-active tyrosine residues (Y_Z and Y_D). Tyrosine Y_Z shuttles electrons from the Mn cluster of the oxygen evolving complex to the oxidized reaction center chlorophyll ($P_{680}^{\bullet +}$), whereas Y_Z has no known function. Recent studies have shown that the rate of electron transfer between Y_D and $P_{680}^{\bullet +}$ at pH > 7.5 is as rapid as that between Y_Z and $P_{680}^{\bullet +}$. Such rapid electron transfer may have important mechanistic implications, one of which is that Y_D could increase the midpoint potential of $P_{680}^{\bullet +}/P_{680}$. To test this possibility, the rate of charge recombination in site-directed *Synechocystis* sp. PCC 6803 mutants having Y_D replaced with phenylalanine or glycine was measured. An acceleration of charge recombination between $Q_A^{\bullet -}$ and $Y_Z^{\bullet}$ was measured in isolated PSII reaction centers with optical absorbance spectroscopy, a result consistent with $Y_D^{\bullet}$ raising the midpoint potential of $P_{680}^{\bullet +}/P_{680}$. However, no acceleration of charge recombination between $Q_A^{\bullet -}$ and the partially oxidized Mn cluster was measured with fluorescence, a result consistent with $Y_D^{\bullet}$ not affecting the midpoint potential of $P_{680}^{\bullet +}/P_{680}$. Additional experiments are underway to solve this apparent paradox.

72 FIELD VALIDATION OF CHRONIC SUBLETHAL DREDGED MATERIAL LABORATORY BIOASSAYS: PROGRAM DESIGN

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Federal regulations require the evaluation of potential dredged material for unacceptable environmental effects prior to disposal. Standard evaluation of dredged material includes measuring acute toxicity in benthic organisms over a ten day period in the laboratory, but chronic toxicity is not routinely evaluated. In response to the need for chronic toxicity tests to measure long-term effects, the USACE recently completed the development of two new chronic sublethal bioassays with the marine polychaete worm *Neanthes arenaceodentata* and the estuarine amphipod *Leptocheirus plumulosus.* In order to determine whether these tests accurately predict negative environmental impacts upon the benthic community, a field validation program has been implemented. These two tests have been used to evaluate different concentrations of a selected contaminated sediment and a clean reference sediment. These sediments have been placed in test containers and deployed in the field at a selected test location. At specified intervals during the study the sediments in selected test containers are retrieved and analyzed for infaunal community composition/re-colonization and toxicity. Results of the chronic sublethal laboratory bioassays are compared to effects observed *in situ* to evaluate the ability of the proposed tests to predict impacts on benthic infauna in the environment. In addition, the chronic tests will be compared to the more standard 10-day acute toxicity tests to evaluate whether acute or chronic sublethal tests provide a better prediction of observed benthic community responses.

73 FLOWER DENSITY EFFECTS ON POLLINATION OF ARTICHOKE THISTLE (*CYNARA CARDUNCULUS* L. ASTERACEAE)

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Pollination studies of non-native plant species are few. *Cynara cardunculus* is a non-native, invasive weed of lower elevation coastal regions in central and southern California. Due to the large size and showy appearance of its inflorescence, *C. cardunculus* could have significant impacts on pollination in natural communities; including, competition for pollinators and negative effects on reproductive success of coflowering native species. I investigated how variation in the density of floral display affects pollinator visitation rates and seed set in *C. cardunculus.* Specifically, pollinator visits and seed set were compared between experimental plots of high and low density *C. cardunculus* flowers. Solitary bees and honey bees accounted for the majority of visitors. Although there was significant variation in visitation on a daily basis and throughout the study period, I found no significant difference in pollinator visitation rates or seed set between dense and sparse plots. In addition, flower density had no effect on the number of heads visited per plot. These results suggest that in this system pollinators do not have a preference for patches with greater floral density.

74 COPPER TOLERANCE AND REMEDIATION POTENTIAL OF *SALIX LASIOLEPIS*: A NATIVE CALIFORNIA WILLOW

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Urbanization, manufacturing and agricultural practices have increased copper in many S. California rivers/streams, making it an important waterway contaminant. Increased copper levels may limit success of trees commonly used to remediate degraded wetlands/ riparian areas. We are therefore studying copper tolerance of native CA willows including *Salix lasiolepis* (Arroyo willow). First we conducted small pilot studies of the copper tolerance of asexually propagated *S. lasiolepis* cuttings grown in soilless medium (10–12 weeks under greenhouse conditions). Copper content of the medium was altered with dilute fertilizer solutions containing 0, 0.15, 0.3, 0.7 and 1.0 mg of added $CuSO_4AH_2O$/l. At 10 weeks, cuttings treated with 0.3 and 0.7 mg/l copper sulfate grew more robustly than controls (0.0) or those given 0.15 or 1.0 mg/l copper.

	Group Total at 10 weeks (N=4/group)				
Measure	Control (0.0)	0.15 mg/l	0.3 mg/l	0.7 mg/l	1.0 mg/l
No. leaves	106	36	124	205	76
Leaf dry wt.	0.73 g	0.43 g	1.90 g	2.67 g	0.69 g
Shoot dry wt.	0.14 g	0.08 g	0.64 g	0.66 g	0.15 g
Root dry wt.	0.29 g	0.19 g	0.37 g	0.75 g	0.27 g

At 12 weeks, the group receiving 0.3 mg/l had higher, and that receiving 0.7 mg/l had lower, total leaves and average leaf, shoot and root dry weights than the other groups. These very preliminary results suggest Arroyo willow may be suitable for copper-contaminated riparian sites. We are currently replicating results and extending studies to *Salix gooddingii* (Gooding's willow) and *S. laevigata* (Red willow).

75 WHAT DOES IT TAKE TO BE A HERBIVORE?–GUT STRUCTURE AND FUNCTION IN THREE SPECIES OF NEW WORLD SILVERSIDE FISHES (TELOSTEI: ATHERINOPSIDAE) WITH DIFFERENT DIETS

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We explored the possible diet-related specializations of the gut in stomachless fishes by comparing the brush-border surface areas and enterocyte inclusions (in progress) of the gut epithelium and the digestive enzyme profiles (in progress) in three closely related atherinopsid fishes using electron microscopy and biochemical assays. For these comparisons, we examined proximal, middle and distal regions of the intestine of *Atherinops affinis,* from both kelp forest and estuarine habitats, and *Atherinopsis californiensis* and *Leuresthes tenuis,* both from open coastal habitats. *A. affinis* is generally a carnivore in kelp forests and a herbivore in at least some estuaries, whereas *A. californiensis* is mainly carnivorous and *L. tenuis* strictly carnivorous. Previous work showed that relative gut length in these species generally follows the expectation that carnivores have shorter guts than herbivores and omnivores have guts of intermediate length. The herbivore (estuarine *A. affinis*) showed greater overall microvillar surface area than the two more carnivorous species as well as the carnivorous population of *A. affinis.* Thus, a degree of congruence exists between diet, gut length and absorptive surface area, with the herbivore gut exposing a larger surface area to the ingested food material.

76 FEEDING PREFERENCES AND ASSIMILATION EFFICIENCIES IN THE HERBIVOROUS MARINE SNAIL *LITHOPOMA UNDOSUM* (TURBINIDAE)

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Many studies have examined factors that contribute to food choice in herbivorous marine invertebrates. However, few have considered relationships between preferences and the assimilation efficiencies of food items. The purpose of this research is to establish a preference hierarchy among seaweed foods for the herbivorous marine snail *Lithopoma undosum,* and then to test the hypothesis that preferred seaweeds are assimilated at higher efficiencies than less preferred seaweeds. Differential consumption of seaweeds during three sets of two-choice experiments showed that *L. undosum* exhibits clear feeding choices, preferring kelp species over nine other non-kelp macrophytes. Clear preferences could not be detected among the kelp species tested. Following kelp, the fleshy red alga, *Pterocladiella* *capillacea* was preferred over other species of macrophytes, followed by the calcified coralline *Lithothrix aspergillium,* which was preferred over two known chemically defended species and the seagrass, *Phyllospadix torreyii.* Assimilation efficiencies are now being quantified using an ash marker method. Results to date indicate that *L. undosum* prefers kelps over all other seaweeds, but also exhibits defined secondary preferences among less-preferred seaweed foods.

77 WHENCE HAVE THEY COME, THE ABYSSAL GRENADIERS?

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Truly abyssal species of the grenadier genus Coryphaenoides are relatively few, represented in the eastern North Pacific Ocean only by Coryphaenoides (Nematonurus) armatus variabilis (Günther), Coryphaenoides (Nematonurus) yaquinae Iwamoto and Stein, and Coryphaenoides (Chalinura) leptolepis (Günther). A few other, more poorly known species of subgenera Nematonurus, Chalinura, and Lionurus, inhabit mostly the fringes of the abyss elsewhere. A much higher diversity of Coryphaenoides species is found worldwide on continental slopes between about 500 and 2,000 m. Phylogenetic study of genus Coryphaenoides using allozymes suggested that the abyssal subgenera Nematonurus and Chalinura were sister taxa and likely derived from slope species of Coryphaenoides. However, a second study using DNA sequences from the12s rRNA and COII mitochondrial genes suggested that Coryphaenoides (Nematonurus) species might in fact be sister to all slope-dwelling Coryphaenoides (Coryphaenoides) species, but the second study did not include the abyssal C. (Ch.) leptolepis. We sequenced the relevant portion of the 12s rRNA gene for three more Coryphaenoides species, including C.(Ch.) leptolepis, plus one Caelorinchus species, bringing the total for further analysis to ten ingroup and four outgroup species. Maximum likelihood and maximum parsimony analyses of the 12s sequences suggested that the abyssal species of Coryphaenoides indeed form a sister taxon to the slope-dwelling species of Coryphaenoides, and might represent a separate radiation.

78 PHYSIOLOGICAL RESPONSES TO VARIATIONS IN SALINITY AND NUTRIENTS BY THE BLOOM-FORMING MACROALGA *ENTEROMORPHA INTESTINALIS*: IMPLICATIONS FOR USE AS A BIOINDICATOR OF FRESHWATER AND NUTRIENT INFLUX TO ESTUARINE AND COASTAL AREAS

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Enteromorpha intestinalis is a bloom-forming species of macroalgae associated with eutrophication. The objective of this study was to quantify the response of *E. intestinalis* to two factors that co-occur with eutrophication, salinity reduction and nutrient enrichment. This alga is tolerant of a variety of environmental conditions and responds to changes in salinity and nutrient supply on the cellular level. We performed short-term laboratory experiments to examine the effects of salinity and nutrient supply on tissue water content, potassium concentration, and nutrient content of *E. intestinalis.* These variables were measured because tissue water content and potassium concentration are associated with osmoregulation, and tissue nutrient content indicates nutrient history of the algae. Results revealed that tissue water content decreased significantly with increasing salinity, and this relationship was unaffected by differing nutrient concentrations. Potassium concentration decreased as external salinity decreased, demonstrating its role as an osmolyte. When salinity and nutrients were altered, the same trend for tissue water and potassium emerged. However, the pattern was less pronounced in the presence of higher nutrient concentrations, suggesting that increased nutrient concentration in tissue may also function in osmoregulation. Tissue nutrients increased with increased nutrient supply and this pattern was unaffected by decreased salinity. The ability of this alga to rapidly take up available nutrients for growth and short-term osmoregulation helps to explain the bloom potential of *E. intestinalis.* Further, quantifying the physiological response to environmental change in the field will contribute to our ability to detect changes in the level of eutrophication in coastal systems.

79 THE USE OF AQUATIC INVERTEBRATES TO IDENTIFY ECOLOGICAL TRENDS IN URBAN FRESHWATER STREAMS

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As urban development in Southern California progresses, watershed management issues become increasingly important. Recognition of the effects of non-point source pollution and physical degradation to freshwater streams and drainages can be difficult, and the inclusion of biocriteria in watershed monitoring programs provides a direct measure of ecological response. The California Stream Bioassessment Protocol is a standardized procedure utilizing biological and physical data to assess the effects of water quality over time to a resident invertebrate population. This procedure was used to sample 22 stream monitoring sites in San Diego County in June, 2001. Three reference sites were sampled for comparison. Benthic invertebrates were identified to standard taxonomic levels, and pre-established taxa-based tolerance values were applied to calculate biological indices and provide an indication of community tolerance to urban impacts.

80 COMPARISON OF FEEDING GUILD STRUCTURES OF INTERTIDAL FISHES FROM CALIFORNIA AND CHILE: A MEASURE OF COMMUNITY CONVERGENCE

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Spatially separated intertidal fish communities in similar environments may face the same selection pressures. The intertidal fish community of central California is represented mainly by cottids and zoarcoids, while the intertidal fishes of central Chile are mostly blennioids and no species are common to both communities. We tested the hypothesis that convergent evolution of intertidal fishes from central California and central Chile, both cool-temperate regions, has allowed for community convergence by comparing the feeding guilds of Californian fishes with guilds of Chilean fishes. The diets of the 14 most abundant intertidal fishes from central California waters were determined from fishes collected at San Simeon, Pescadero Point, and Dillon Beach. A phenogram (UPGMA) of dietary similarity was constructed and guild structure determined. The diets of Californian fishes were compared objectively to the diets of 13 Chilean fish species (determined by Muñoz and Ojeda 1997) by creating a second phenogram. Similar resource guilds (e.g., omnivorous, microcarnivorous, carnivorous) were found in California and Chile despite the differing taxonomic affinities of their members. An analysis of ecomorphological characters within feeding guild types from both regions is in progress and is expected to provide further insight into convergent evolution in these two marine fish communities.

81 DIGESTIVE ENZYME ACTIVITY IN HERBIVOROUS AND CARNIVOROUS PRICKLEBACK FISHES (STICHAEIDAE): ONTOGENETIC AND PHYLOGENETIC EFFECTS

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We measured the activities of proteases and carbohydrases in four closely related species of pricklebacks to determine whether these fishes are genetically predisposed to digest a specific diet. Both *Cebidichthys violaceus* and *Xiphister mucosus* shift to a more herbivorous diet as they grow (≥45mm SL), whereas *X. atropurpureus* and *Anoplarchus purpurescens* remain carnivores throughout life. Protease (pepsin, trypsin, aminopeptidase) and carbohydrase (amylase, maltase, isomaltase) activities of small (30–40mm SL) carnivorous fish were compared with larger (60–75mm SL) fish raised on a high-protein animal diet and with larger (60–75mm SL) wild-caught fish that had consumed a natural diet. *A. purpurescens,* a member of a carnivorous clade, appears adapted to a high-protein diet because it showed higher trypsin and aminopeptidase but lower amylase activity than the other fishes, and, uniquely, increased trypsin activity when fed the high protein diet. The three other species, members of an adjacent largely herbivorous clade, showed a significant increase in amylase activity with size, even on the high-protein diet. The increase in amylase activity in *C. violaceus* and *X. mucosus* indicates that the shift in diet and enzymatic activity may be genetically fixed, whereas in *X. atropurpureu.* the increase may result from phylogenetic constraints.

82 REGULATION OF PROTEASE EXPRESSION IN THE CARNIVOROUS PLANT *NEPENTHES ALATA*

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Many plants have evolved carnivory as a means of acquiring nitrogen. Unlike other means of acquiring nitrogen, such as uptake by root or symbiosis with microbial species, carnivory requires considerable investment of resources into production and maintenance of traps and hydrolases, digestive enzymes. One means to maximize the benefits and minimize the costs of carnivory is the regulation of hydrolases so that they are expressed only in presence of prey. In this study, the presence of signal-based regulation of protease, protein-digesting enzyme, expression in a pitcher plant *Nepenthes alata* was investigated using two different protease assays. Induction of protease expression upon addition of nitrogenous compounds was observed in *Nepenthes alata* suggesting that this species regulates its proteolytic activity based on presence of prey. The pH of the fluid in pitchers was also found to be regulated by the presence of prey. In addition, a developmental regulation of proteolytic activity was observed after opening of the pitchers in absence of prey. These data suggest that *Nepenthes alata* utilizes both signal-based and developmental regulation of proteolytic activity to increase its chance of surviving by improving cost:benefit ratio of carnivory.

83 EFFECTS OF *IN-UTERO* COCAINE EXPOSURE ON THE DEVELOPING BRAIN

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To understand the effects of maternal drug addiction on the child's neurodevelopment and behavior, two groups of children aged 3 to 13, one prenatally exposed to cocaine and the other unexposed control, were tested last year in a pilot study at the Harbor UCLA Imaging Center. The database contains individual Child Behavior Check List (CBCL) survey scores, as well as and volumes of different brain regions and concentrations of metabolites from Magnetic Resonance Imaging and Spectroscopy (MRI and MRS). Based on statistical analysis, abnormality (or tendency toward it) with prenatal exposure to cocaine is significant ($p\text{-value} < 0.05$) in most behavior categories, and particularly strong in aggressiveness, delinquency, and attention deficiency, all three of which seem to correlate well with each other. Also, the exposure diminishes the volumes of midbrain (20%) and cerebellum (10%) as statistically significant, but only when the volumes are scaled with the whole brain volume. Further, the exposure is found to produce substantial and statistically significant increases in the spread of data (standard deviations) in most of these variables, particularly in CBCL scores. The major behavior and physiological effects appear consistent with current neuro-science literature and suggest explanatory speculation about the prominent role of the dopamine neuro-circuitry.

84 NEUROANATOMIC OBSERVATIONS OF THE BRAIN IN AUTISM: NEUROIMAGING STUDIES USING THE TECHNIQUE OF COREGISTRATION

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Background and Purpose. Autism is a developmental disorder of brain function. Autistic patients are characterized by their aloofness, obsession with repetition, and avoidance of social contact. Early neuroimaging studies in autism failed to prove the significance that the cerebellum and limbic system have on autistic behaviors. The purpose of the study is to investigate the relationship among the limbic system, cerebellum, and autism using the technique of coregistration, a process whereby an examination scan of a patient is matched up with and corrected according to an atlas through mathematical transformations. *Methods.* HMPAO-SPECT brain images were obtained through coregistering 3 groups of autistic patients categorized by the seriousness of autistic traits a patient displays, and coregistering 1 control group of the normal population. Values of uptake of each brain region of interest of the 3 autistic groups are then compared with those of the normal group to look for any abnormality. *Results.* The cerebellum and the limbic system were found to be abnormal with respect to normal brains. Furthermore, the cerebellum is associated with the lack of emotion displays characteristic of autistic patients, and the limbic system is linked with autistic patients' incapability to process new information and therefore an affinity for repetitive activities. *Discussion.* Using the process of coregistration, the study proves that the limbic system and cerebellum are associated with autistic behaviors.

85 ON THE EFFECT OF LIGHT INTENSITY ON THE ELECTRICAL CONDUCTIVITY OF FILAMENTOUS FUNGI

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Molds, or filamentous fungi, consist of hyphae, long strings of cells. Some are septate, having walls that separate one cell from the next. Others are coenocytic; they are continuous, elongated cell bodies with multiple nuclei. Fungi feed by secreting digestive enzymes that hydrolyze their substrates, the organic matter on which they grow, releasing nutrients, which they absorb through their cell walls. When the mycelium, the body of a fungus, secretes hydrolytic enzymes, its electrical conductivity should increase. I hypothesized that the electrical conductivity of the fungus would be higher when it grew under intense illumination, because it would be adaptive for the fungus in its natural environment to secrete greater quantities of digestive enzymes when more light fuels photosynthesis in the plants on which the fungus grows. To test this hypothesis, I grew several cultures of Neurospora discretia under different lighting conditions and tested the electrical resistance of a sample of approximately equal size from each culture. I found no distinct correlation between the conductivity of the fungus and the intensity of the light under which it grew.

86 INTERNUCLEOSOMAL DNA CLEAVAGE DETECTED IN MK-801 INDUCED RATS BUT SHOW NO SIGN OF CASPASE-3 ACTIVATION IN CELL DEATH

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Neuronal apoptosis is produced in the neocortex by administration of the NMDA-receptor antagonist MK-801 in neonatal rats, but whether programmed cell death (PCD) mechanisms are involved is not known. This study was undertaken to determine if internucleosomal DNA cleavage (DNA laddering) and caspase-dependent PCD occurs in apoptotic neurons. Control and MK-801 groups with 6 or 24 h survival underwent either (1) transcardiac brain perfusion-fixation with 4% paraformaldehyde for H & E, TUNEL and CM1 antibody (to active caspase-3) staining, or (2) decapitation and rapid dissection and homogenization of neocortex for DNA gel electrophoresis, Western blot analysis of active caspase-3 and activity of endogenous caspase-3-like activity (DEVD-AFC cleavage assay). Thymuses of adult rats given methamphetamine (MAP), to produce apoptotic thymocytes, or saline were used as controls for caspase-3 activation. Following MAP treatment, apoptotic thymocytes showed TUNEL and CM1 antibody positivity, DNA laddering and a 25-fold increase of DEVD-AFC cleavage (1.13 ± 0.11 vs. 0.05 ± 0.01 units/:g protein, mean ± SE, n = 3). TUNEL-positive neurons were found in the retrosplenial (RS) and fronto-parietal cortices and ventromedial thalamic nucleus at 24 but not 6 h survival. Some of the TUNEL-positive neurons also showed CM1 antibody positivity. DNA laddering also occurred in neocortex at 24 but not 6 h survival. However, DEVD-AFC cleavage activity was not increased and the active caspase-3 (p17) fragment was not found by Western blot in the MK-801 treated rats. The data suggests that caspase-3 activation may occur in individual apoptotic neurons but that widespread caspase-3 activation does not occur.

87 URBANIZATION OF COASTAL WATERS B CONCOCTING HORMONAL CHAOS

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Greater Los Angeles is a highly urbanized metropolis that uses an abundance of chemicals everyday. As a result, it is quiet possible that there are increased concentrations of endocrine disruptive contaminants in the environment surrounding and part of Greater Los Angeles, where they can hinder and alter healthy endocrine function in many organisms including but not limited to humans and wildlife.

In an effort to assess the endocrine disruptive potential of the environment around Greater Los Angeles, a study was conducted involving the environmental sampling of 20 male *Pleuronichtys verticalis* at five trawling sites (n = 4 at each site) in the coastal waters off of Greater Los Angeles, and the use of 3 male *Pleuronichtys verticalis* as controls acquired from Dana Point, CA and acclimated in the lab. All 23 *Pleuronichtys verticalis* were blood sampled and assayed for vitellogenin, an estrogen induced egg yolk protein not typically produced in males but inducible in the presence of endocrine disruptive estrogenic stimuli.

The results show that environmental exposure to the urbanized coastal waters off Greater Los Angeles does in fact result in endocrine disruption. The results also indicate that there is no difference between one portion of the coastal water and another with regards to endocrine disruptive potential. The potential is uniformly distributed over the coastal waters. Errors include inadequate sample size, in adequately quantifiable data, and questionable sourcing of controls which may have affected the results.

88 CORRELATION DYNAMICS IN ACIRCUIT MOLECULES@ WITH CHAOTIC LINKS

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Correlation phenomena in original circuit networks based on chaotic links with different structural complexities and different dimensions were studied. The circuits demonstrate rich spatio-temporal behavior including a new phenomenon, remote correlation, when correlation between remote nodes is stronger than correlation between any other pair of neighboring nodes. This work also demonstrates a new jitter generator circuit with possible applications to secure communications.

A new approach was used to synthesize the networks. The network geometry mimics chemical molecules with high spatial symmetry. The Abonds@ connecting circuit nodes (positions of Aatoms@) are replaced with chaotic links based on the jitter generator. Waveforms, phase portraits, and power spectrums were investigated, and correlation functions were calculated for interesting cases. The results contribute to the spatio-temporal phenomena in complex systems.

89 DISTRIBUTION OF OXIDATIVE AND GLYCOLYTIC ENZYMES IN ELECTROCYTES OF PHYLOGENTICALLY DIVERSE SPECIES OF FISH

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Electric fish generate energy and produce an electric current from electrocytes which are derived from muscle tissue. The type of energy metabolism that creates ATP in the electrocytes can vary, possibly depending on the type of muscle the electrocyte has evolved from, either fast or slow. The goal of this research is to determine how various electric fish generate ATP in their electric organs. Enzyme histochemistry and immunohistochemistry was used to localize glycolytic and oxidative metabolic enzymes in electrocytes of the electric fish *Gnathonemus,* commonly known as the elephantfish. These findings were then compared to those found in other species of electric fish, such as *Sternarchus albifrons.* By examining the distribution of metabolic enzymes, in can be seen that electrocytes utilize one or both metabolic pathways, either oxidative respiration or glycolysis, in the production of ATP.

90 THE EFFECT OF LIGHT ON THE ACCUMULATION OF THE NUCLEAR-ENCODED *psbA* BINDING PROTEINS IN VASCULAR PLANTS

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In the unicellular green alga *Chlamydomonas reinhardtii,* the RB47 proteins accumulate in response to light, while the RB38 and RB60 protein accumulates constitutively. These three nuclear-encoded proteins bind to the 5′-untranslated region of the chloroplast-encoded *psbA* mRNA to initiate the synthesis of the photosynthetic D1 protein. Using immunoblot analysis and antibodies raised against RB38, RB47 and RB60 from *C. reinhardtii,* we hypothesized that the protein accumulation would occur in one of three manners: constitutive, chloroplast-induced, or light-induced in two vascular plants: bean (*Phaseolus vulgaris*) and pea (*Pisum sativum)* using *C. reinhardtii* as our control. The objective was to show that *C. reinhardtii* and vascular plants contained the same proteins involved in D1 synthesis, in hopes that we could one day apply what is known about the photosynthetic processes in *C. reinhardtii* to vascular plants and thus further enhance our understanding of photosynthesis. The anti-RB38 antibody recognized a 54.9-kD protein in *P. vulgaris.* In light and developmental studies, this 54.9-kD protein accumulates in light- and dark-grown bean shoots, as well as dark-grown bean roots. Anti-RB60 recognized a 60-kD protein in both shoots and roots, although reduced in both dark-grown shoots and roots, as compared to light-grown shoots. The anti-RB47 recognized a 47-kD protein in only light-grown shoots, and not dark grown shoot or roots.

92 THE EFFECTS OF ENDOTHELIAL POLARITY AND ALZHEIMER'S DISEASE ON MONOCYTE MIGRATION IN THE HUMAN BRAIN

Wei Liang. Alhambra High School, Alhambra, CA, 91801; University of Southern California, Department of Biochemistry and Molecular Biology, Los Angeles, CA

Amyloid $-peptide (A$) is a protein present on both sides of the human blood-brain barrier (BBB). In patients with Alzheimer's disease and other with A$-related disorders, it accumulates, increasing the migration of monocytes across the BBB by interacting with certain proteins, two of which were shown to be A$ receptor RAGE (receptor for advanced glycation end products) and PECAM-1 (platelet endothelial cell adhesion molecule). This study examines the effect of polarity (the presence of Aβ on the luminal or abluminal side of the BBB) on A$, RAGE, and PECAM-1 mediated monocyte migration. Transwell chambers were used to simulate the brain endothelium and A$ was added to the top (luminal) or bottom (abluminal) compartments to induce the migration of monocytes across a monolayer of human brain microvascular endothelial cells (HBMVEC). Results from normal as well as Alzheimer's disease endothelial cells were compared. The results show that in normal endothelium, luminal Aβ is able to induce a higher rate of migration, while in Alzheimer's endothelium, polarity of Aβ is insignificant. Furthermore, Alzheimer's endothelial cells react more readily with Aβ, especially when it is abluminal, resulting in increased migration of monocytes as compared to normal endothelial cells.

93 DNA STRUCTURE AFFECTS SODIUM BISULFITE CONVERSION OF NUCLEOTIDES

D.M. Chen and C.L. Hsieh. University of Southern California/Norris Cancer Center, Department of Urology, Los Angeles, CA, 90033-0804

Sodium bisulfite conversion efficiency is essential in mapping methylation patterns in DNA sequences. Past research has shown that sequences with cytosines adjacent or near methylated cytosines acquire partial resistance to full conversion. Different oligonucleotides with inverted repeats were designed to form hairpin loop structures to test efficiency of the sodium bisulfite reaction method. The loop structures had different arrangement of bases and were tested for the order in which the cytosines in the stem of the structure can no longer be fully converted under the reaction temperature of 55E Celsius. Each sequence had 2 matching base pairs at the base of the structure. The status of the different sequences (DC-1, DC-2, DC-3, DC-4) after undergoing the sodium bisulfite reaction turned out to be full conversion. Hairpin loop structures with a small number of matching bases at the foot of the sequence do not affect the efficiency of the sodium bisulfite reaction.

94 THE EFFECTS OF UROKINASE-TYPE PLASMINOGEN ACTIVATOR (uPA) INHIBITION ON CRANIAL NEURAL CREST MIGRATION

H.L. Marr and M.A.J. Selleck. University of Southern California, Keck School of Medicine, Department of Cell and Neurobiology, Los Angeles, CA, 90089

Neural crest cells play an important role in embryonic development as they differentiate into components of the central and peripheral nervous systems, vascular system, and muscle tissue. Urokinase-type Plasminogen Activator (uPA) has been speculated to convert plasminogen into plasmin, which degrades the extracellular matrix and provides a pathway through which neural crest cells migrate. In order to determine the direct role uPA plays in neural crest migration, young chick embryos were cultured (either in New culture or Window culture depending on embryo stage) in the presence of a 1mM Amiloride solution, a diuretic drug known to inhibit uPA. By knocking out uPA, it is possible to deduce the role it plays in cranial neural crest migration. Performing immunohistochemistry labeling for *Hnk-1* has allowed us to examine the patterns of crest migration. Results indicate that uPA is vital for migration: its inhibition prevents the migration of neural crest and also plays a part in preventing neural tube closure. Its greatest effect is seen in young stage 4 embryos, where a drastic decrease in migration is shown as compared with control embryos. Knowledge of neural crest migration and neural tube closure requirements can be applied to induce migration in crest cells that have failed to do so.

95 GENETICS OF DAUER LARVAE FORMATION IN CAENORHABDITIS BRIGGSAE

S. Phan and I. Takao, California Institute of Techology, Department of Biology, Pasadena, CA, 91125

Caenorhabditis briggsae, a sister species of *Caenorhabditis elegans* evolved from evolution about 60,000 years ago. Exactly how different these two nematode species is not clearly understood. To tackle the problem, a comparison of the dauer larvae stage in which nematodes can undergo for six month without feeding and all growth development halted can provide a leading clue to the differences exhibited by both nematode species. A mutagenesis was conducted to the wildtype strain of *C. briggsae* to screen for dauer mutants to compare with the C. elegans dauer mutants. A series of test was conducted to analyze the mutants of *C. briggsae.* In conclusion, the analysis showed that the daf-13 gene in *C. elegans,* which is X-linked and responsible for causing Sodium Dodecyl Sulfate (SDS) sensitive in *C. elegans* has a different function in *C. briggsae.* Also, the daf-4 gene that causes dauer mutation is not temperature sensitive in *C. briggsae* than in *C. elegans.*

96 RETROVIRAL-MEDIATED TRANSFER AND EXPRESSION OF THE NEOMYCIN AND HYGROMYCIN B DRUG RESISTANCE GENES

Annie Li and Vicky Sung, Dr. Michael Lai Research Group, University of Southern California School of Medicine, Department of Molecular Biology and Immunology, Los Angeles, CA, 90033

The application of an efficient retroviral vector serves as an important tool in gene therapy and genetic analysis of a variety of genes. Transferring a drug resistant gene is primarily useful during selection of transformed cells containing both the drug resistance gene and a desired gene. Although past studies have succeeded in transferring the neomycin drug resistance gene (NeoR) within cells, no studies have been conducted with the hygromycin B drug resistance gene (HygroR) or both HygroR and NeoR. In this experiment, the Murine Leukemia Virus (MLV) pseudotyped with the Vesicular Stomatitis Virus glycoprotein (VSVg) was used to transduce the NeoR and HygroR within a 293 cell line, human embryonic kidney cell line. 48 hours after infection, cells expressing drug resistance were selected by applying 500 _g/ml of G418 and/or 150 _g/ml of hygromycin B to 10% Fetal Bovine Serum (FBS) Dulbecco's modified Eagle's medium (DMEM). The number of 293 cells surviving toxic levels of G418 and/or Hygromycin B drug application was counted weekly with the Trypan Blue Exclusion Assay. This system successfully transferred and expressed the drug resistance genes within 293 cells, but was not able to sustain the expression of hygromycin B resistance for more than a week. Currently, the neomycin resistant cells are still being cultured and experimented with in order to determine the length of time of its gene expression.

97 BROCA'S AREA'S CRITICAL ROLE IN IMITATION

Jake Marcus, Crossroads School, Santa Monica, CA, 90404, Marc Heiser, UCSF, San Francisco, CA, 94143, Fumiko Maeda, Marco Iacoboni, Ahmanson Lovelace Brain Mapping Center, Los Angeles, CA, 90095

To determine if Broca's area plays a critical role in human imitation, we conducted a repetitive transcranial magnetic stimulation (rTMS) study, transiently disrupting cortical activity in three sites:

the left inferior frontal gyrus (Broca's area), right inferior frontal gyrus, and an occipital control condition. Stimuli consisted of sequences of key presses by a left hand (action to be imitated). The subjects had a button pad and used the right hand to press the keys instructed by the 'action to be imitated' (imitation task). To ensure the rTMS pulses were not stimulating motor paths causing interruption in the imitation task, a visuomotor control task was designed. In this task spatial cues (red dots appearing over the keys) instructed the subjects which keys to press. No differences were observed between the inferior frontal cortexes and occipital site. If Broca's area were critical to imitation then the subject would not perform well in the imitation task while Broca's area was disrupted. Stimulation of the occipital control site should yield the highest accuracy. The results confirmed our predictions supporting the concept that Broca's area is critical to imitation. Broca's area, a language processing and speech production region, now also demonstrated to be critical to imitation, suggests that imitation may have been an evolutionary precursor of more complex communicative abilities in humans.

98 OXIDATION OF SUBSTIUTED PHOSPHINES WITH SINGLET OXYGEN: INTRA- VS. INTER-MOLECULAR PATHWAYS

Timothy Dong, Dr. Matthias Selke, California State University, Los Angeles, Dept. of Chemistry, Los Angeles, CA 90032

Reaction between singlet oxygen and *tris(ortho-methoxyphenyl)phosphine* resulted in the formation of both phosphine oxide and *orthomethoxyphenyl-di(orthomethoxyphenyl) phosphinate,* more simply referred to as insertion product. The insertion product resembles phosphine oxide except for the additional presence of an oxygen atom located between the phosphorus and carbon atom of one of the three phenyl rings attached to the phosphorus atom. By comparing the product distribution of phosphine oxide and insertion product, a ratio of the rate constants for the oxide pathway and the insertion pathway was obtained. From this, it has been concluded that formation of insertion product increases with polarity and decreases with increased concentration. It is believed that formation of phosphine oxide proceeds via the inter-molecular pathway, while the insertion product proceeds via the intra-molecular pathway. These results can also be applied toward controlling the distribution of product yield of phosphine oxidation based on the initial concentration of phosphine used and the polarity of the solvent employed—providing a convenient alternative in mediating an otherwise complicated combination of intra- and inter-molecular reactions.

99 INFLUENCES ON THE SELECTION OF SCIENCE AS A STUDY AND CAREER

Lisa Marin-Burkhart, Claremont Graduate University

Mediocre performance of U.S. students on national and international science assessments continues despite years of science education reform. Is there evidence of success for the various initiatives seeking to increase equity and diversity among scientists? Can we truly achieve "science literacy for all"? How do we answer the question, "Who will do the science of the future?"

This study asked a sample of scientists and college science majors (N = 64) spanning the ages of 18–65 to reflect upon influences that helped shape and develop their interest in science. Using both Likert-scale items and personal notations, respondents provided insights into the growth of those who do become scientists. Similarities and differences between genders and disciplines as well as among age cohorts were assessed. A distinct improvement in the perception of gender bias was noted, with written responses revealing dramatically how times have changed.

100 A COMPARISON OF THE VOCALIZATIONS OF TWO SPECIES OF FLYING FOXES IN THE SAMOAN ARCHIPELAGO

Eiler, K; J. Newmark; B. Drummond; C. Stewart; and S. Banack, California State University, Department of Biological Science, Fullerton, CA 92831

Most mammals use audible vocalizations to communicate but few studies have documented the extent, range, or distinctiveness of these calls. We report acoustic communication in two species of flying fox that coexist in the Samoan archipelago, *Pteropus samoensis* and *P. tonganus.* Flying foxes are large fruit and nectar eating bats restricted to the Old World. They are members of the suborder Megachiroptera and the family Pteropodidae. There are 60 recognized species in the genus *Pteropus.* Species include the largest living bats, with wingspans up to 1.7 meters. No species of flying fox echolocates, a trait ubiquitous in Microchiropterans. Communication within and between species involves audible calls but remains largely unstudied. We compared the vocalizations of *P. samoensis* and *P. tonganus* from Tutuila, American Samoa in June 2001 using a Senheiser MKH-70 P 48 directional microphone, Sony digital audio tape recorder TCD D 10 PRO II, and Canary bioacoustical software for analysis. *P. samoensis* is a largely diurnal species that roosts within trees either singly or in small family groups (male, female, and single offspring). It is highly territorial and actively defends its territory against intruders. Vocal communication is the primary means used to deter other flying foxes from landing within an occupied territory. *P. tonganus* is a nocturnal species and roost in large noisy camps with up to 5000 animals congregated in adjacent trees. Interactions between the two species are minimal. Variation between populations and species were examined from sonograms using five parameters: peak frequency, pulse rate, maximum frequency, frequency 1 (high frequency of the peak harmonic) and number of harmonics.

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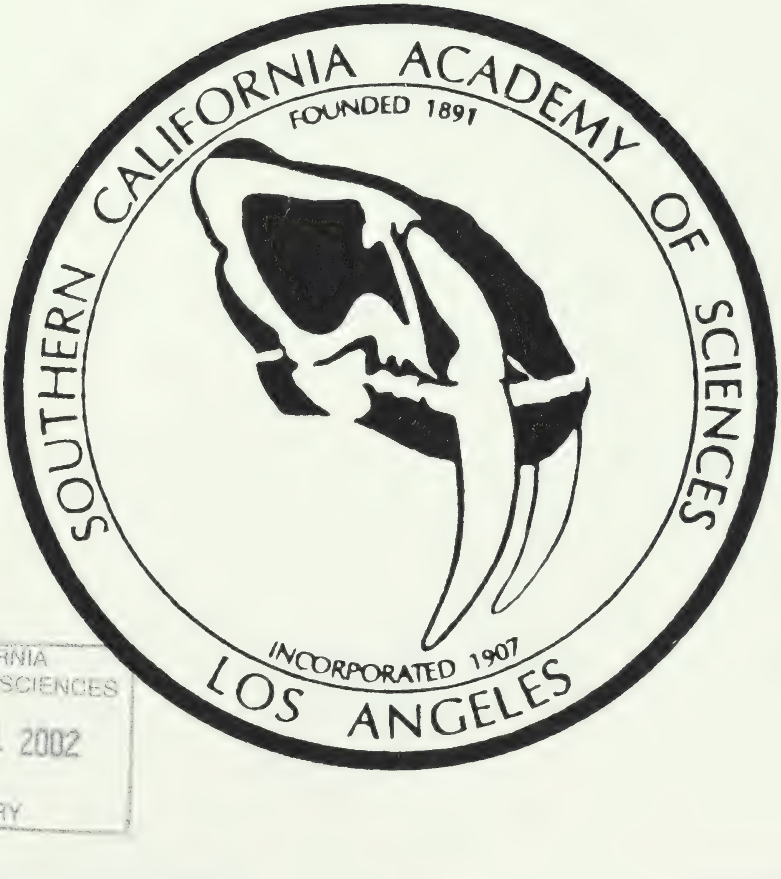
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SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

CALL FOR PAPERS

2003 ANNUAL MEETING

May 2–3, 2003

CALIFORNIA STATE UNIVERSITY NORTHRIDGE

Contributed Papers & Posters: Both professionals and students are welcome to submit abstracts for a paper or poster in any area of science. Abstracts are required for all papers, as well as posters, and must be submitted in the format described below. Maximum poster size is 32 by 40 inches.

Symposia: The following symposia are planned at the present time. If you wish to participate or to organize any additional symposia, please contact the organizer or the Academy President, Ralph Appy (310 732 3497) rappy@portla.org. Organizers should have a list of participants and a plan for reaching the targeted audience.

Reef Ecology—Dan Pondella: *pondella@oxy.edu*

Science Ed—Judy Lemus: *jdlemus@usac.edu*

Declining Fisheries—Jim Allen: *jima@sccwrp.org*

Estuarine Ecosystems—Ray Wilson: *rwilson1@csulb.edu*

Air Quality—Ralph Appy: *rappy@portla.org*

Terrestrial Non-indigenous/Exotic Species—Dan Guthrie: *dguthrie@jsd.claremont.edu*

Zoo-archeology—Dan Guthrie: *dguthrie@jsd.claremont.edu*

Bioremediation—John Roberts: *jroberts@dhvx20.csudh.edu*

There will be additional sessions of Invited Papers and Posters and of papers by Junior Academy members.

Abstracts of presented papers and posters will be published in the August issue of the Bulletin.

Student Awards: Students who elect to participate are eligible for best paper or poster awards in the following categories. Biology: ecology and evolution, biology: genetics and physiology, physical science. A paper by any combination of student and professional co-authors will be considered eligible provided that it represents work done principally by student(s). In the case of an award to a co-authored paper, the monetary award and a one year student membership to the Academy will be made to the first author only.

For further information on posters, abstracts, registration and deadlines, see the Southern California Academy of Science web page at: www.lam.mus.ca.us/~scas/

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Feeding Ecology of Juvenile Kelp Bass (*Paralabrax clathratus*) and Barred Sand Bass (*P. nebulifer*) in Punta Banda Estuary, Baja California, México

Manuel Mendoza-Carranza and Jorge A. Rosales-Casián

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Abstract.—Kelp bass (*Paralabrax clathratus*) and barred sand bass (*P. nebulifer*) diets are analyzed between seasons at Punta Banda estuary, Baja California, México (1992–1993). Beam-trawl and otter-trawl tows (5m depth) collected kelp bass of 40-110mm SL range, and *P. nebulifer* of 30-230mm; overall, gammarid amphipods dominated their diets in index of relative importance, (IRI; 79.4% and 50.9%, respectively). In kelp bass, gammarids had highest IRI in summer (89.3%) and winter (74.9%), with a fish occurrence of 1.6–12.2%, and eelgrass remains of 0.8-7.1%. In *P. nebulifer,* summer to winter IRI of gammarids were 40.0–88.4%, and occurrence (43.8–65.6%), numeric (65.2–95.0%), and weight (2.5–49.8%). Kelp bass and barred sand bass numeric diet breadth in summer were 0.038 and 0.12, respectively, and 0.031 and 0.013 in winter; for kelp bass, weight diet breadth were 0.031–0.27, and for barred sand bass 0.18–0.26. Dietary overlap between basses was low (<0.60), and by seasonal numbers (<0.49) and weights (<0.24). Numeric diet breadth was influenced by small prey with high numeric dominance (gammarids). Despite the low niche overlap at Punta Banda estuary, both species showed close trophic affinities by occupying eelgrass beds and adjacent areas.

The Punta Banda estuary and San Quintin bay are the two most extensive coastal lagoons along the Northern Pacific Coast of Baja California, México (Rosales-Casián 1997a,b). These lagoons are very important nursery grounds, providing abundant food and a decreased predation risk for many juvenile fishes (Navarro-Mendoza 1985; Castro-Longoria and Grijalva-Chon 1988; Hammann and Rosales-Casián 1990; Rosales-Casián and Hammann 1993; Rosales-Casián; 1997a,b). Some of the fish species inhabiting these environments are of commercial and recreational importance, including California halibut (*Paralichthys californicus*), kelp bass (*Paralabrax clathratus*) and barred sand bass (*Paralabrax nebulifer*) (Hammann and Rosales-Casián 1990; Ono 1992; Rodriguez-Medrano 1993; Rosales-Casián 1997a,b).

In Punta Banda estuary, juvenile kelp bass and barred sand bass are important constituents of the assemblage, and are abundant throughout the year (Rosales-Casián and Hammann 1993; Rosales-Casián 1997a,b) exhibiting a spatial and temporal overlap (Sálome-Sanchéz 1994, Pintos-Terán 1994, Mendoza-Carranza 1995). These species present a similar morphology (Feder et al. 1974), and this

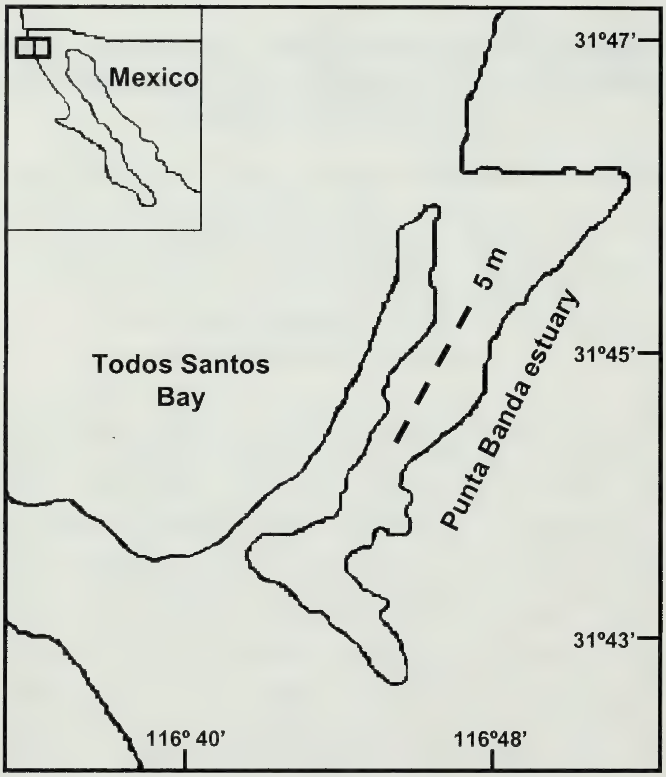

Fig. 1. Beam-trawl and otter trawl sampling sites for kelp bass and barred sand bass collections in the Punta Banda estuary (1992–93).

can imply a possible competition for food (Turner et al. 1969). Therefore, resource partitioning is an important issue in understanding the structure and dynamics of species with similar habits and morphology (Hyslop 1980, Cabral 2000). This study describes and compares the feeding habits of kelp bass and barred sand bass in the Punta Banda estuary, and considers the seasonal variation in diet.

Methods

Study Area

The Punta Banda estuary is located in the North Pacific of Baja California Peninsula at southern side of Todos Santos Bay, Ensenada (31°40′–31°48′N, 116°04′–116°40′W). The L-shaped estuary covers an area of 21 km^2, communicating with the bay through a narrow mouth (<200 m) in its northwest side; it is separated from the bay by a 7.5-km-long sand bar (Figure 1). The estuary has a median depth of 5 m, and its channel can reach 8 m depth. It is a protected habitat, with *Zostera* and *Spartina* beds (3.3 km^2), mud and sandy bottoms (Ibarra-Obando and Poumian-Tapia 1992).

Sampling Methods

Samples were taken monthly from May 1992 to April 1993 (Rosales-Casián, 1997a,b). Collections were made with a beam-trawl (1.6 m wide, 0.4 m high, 3 mm mesh netting) and an otter-trawl (2.5 m by 7.5 m, 5 mm mesh in body and 3 mm in bag end). Five-minute tows (four monthly replicates) were made along the 5 m depth contour at approximately 0.75–1.0 m/sec (1.5–2.0 knots).

Kelp bass and barred sand bass were measured (standard and total length) to the nearest millimeter, and weighed (total and somatic weight) to the nearest gram. The stomachs were extracted by cutting the anterior side of the esophagus and pylorus; they were fixed in 10% formaldehyde buffered with sodium borate.

Seasonal Classification

Bass were classified into two seasonal groups based on monthly surface and bottom temperature (measured with a reversing thermometer) to examine possible variation in diet. The two seasonal periods were: summer (April–October) with warm temperatures (19.9°C ± 1.4 SD); and winter (November–March) with cold temperatures (16.6°C ± 1.1 SD) in accordance with Rosales-Casián (1997a,b), and Mendoza-Carranza and Rosales-Casián (2000).

The seasonal sizes of kelp bass and barred sand bass were tested for homogeneity of variances using Levine's test (Zar, 1984). We used the multiple analysis of variance (MANOVA; Zar, 1984) to test for statistical differences among standard lengths of kelp bass and barred sand bass seasonal groups.

Stomach Content Analysis and Data Analysis

The contents of 136 (58 summer, 78 winter) kelp bass and 134 (100 summer, 34 winter) barred sand bass stomachs were examined. Prey items were identified to the lowest taxonomic level, counted, and wet weighed to the nearest 0.001 g. After data collection, prey items were grouped into higher-level taxonomic categories.

The relative importance of each prey item was expressed as percent of numerical abundance (%N), weight (%W) and frequency of occurrence (%F) (Hyslop, 1980), and were used to calculate the index of relative importance (modified from Pinkas et al. 1971):

$$\mathrm{IRI} = (\%\mathrm{N} + \%\mathrm{W}) \times \%\mathrm{F}$$

Diet differences between species and seasons were tested using the G-statistic (Crow 1981; Sokal and Rohlf 1981).

Feeding activity was evaluated by the feeding intensity index, expressed as the total weight of food, divided by the somatic weight of fish and expressed as percentage. To detect seasonal differences of feeding intensity by species, we used the non-parametric Kruskal-Wallis ANOVA because homogeneity of variances was rejected ($P < 0.01$, Zar 1984). The vacuity index was defined as the percentage of empty stomach (Hyslop 1980).

Diet breadth was calculated using Levin's standardized index (Hurlbert 1978; Krebs 1989):

$$B_i = (n - 1)^{-1} \times [(\Sigma\, jp^2_{ij})^{-1} - 1]$$

where B_i = Levin's standardized index for predator i; p_{ij} = proportion of diet of predator i that is made up of prey j, and n = number of prey categories. The index varies from 0 to 1; low values indicate diets dominated by few prey items and high values indicate generalist diets (Gibson and Ezzi 1987; Krebs 1989).

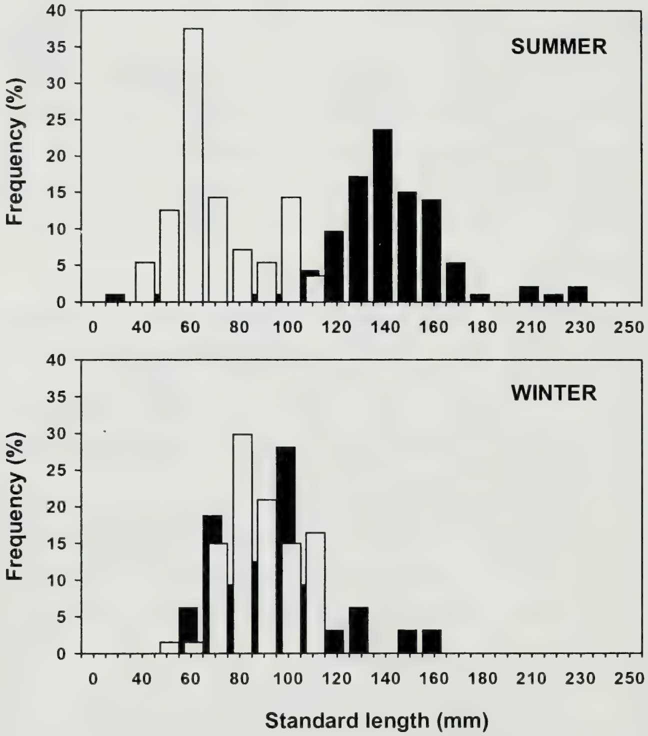

Fig. 2. Length-frequency distribution of kelp bass ☐ and barred sand bass ■ during summer and winter from Punta Banda estuary.

Diet overlap was calculated using the simplified Morisita's index (Krebs 1989, Hall et al. 1990):

$$C_{ik} = 2\left(\sum_{j} p_{ij} \times p_{kj}\right) \Big/ \left(\sum_{j} p^2_{ij} + p^2_{kj}\right)$$

Where C_{ik} = the simplified Morisita's index for predators i and k; p_{ij} and p_{kj} = proportions of each food item inside predator's stomachs. Diet overlap increases as the Morisita's index increase from 0 to 1. Overlap is generally considered to be biologically significant when the value exceeds 0.60 (Wallace 1981; Wallace and Ramsay 1983; Labropoulou and Eleftheriou, 1997). Diet and overlap breadth was estimated using the numerical abundance and biomass of prey items found in the stomachs. Bias-corrected bootstrap 95% confidence intervals, based on 1000 simulations, were used to estimate the reliability of these indices (Efron 1979, Efron and Tibshirani 1986, Hall et al. 1990, Labropoulou and Eleftheriou, 1997).

Results

Size Structure of Predator Groups

During summer, kelp bass ranged from 40 mm to 110 mm with a maximum frequency (37.5%) in the 60 mm size class; barred sand bass size ranged from 30 mm to 230 mm, with maximum frequency (23.6%) in the 140 mm size class (Figure 2a). During winter kelp bass ranged from 50 mm to 110 mm, with max-

Table 1. The percentage composition by frequency of occurrence (%F), numerical abundance (%N), weight (%W), and relative importance (%IRI) (see text) of the annual diet of kelp bass (*Paralabrax clathratus*) and barred sand bass (*P. nebulifer*) in Punta Banda estuary, Baja California, México.

		Paralabrax clathratus				*Paralabrax nebulifer*			
Taxon	Prey	%F	%N	%W	%IRI	%F	%N	%W	%IRI
Plantae		7.27	0.50	1.15	0.12	11.72	0.66	0.29	0.15
Potamotonaceae	*Zostera marina*	7.27	0.50	1.15	0.12	10.94	0.62	0.22	0.12
Alariaceae	*Egregia* sp.					0.78	0.04	0.07	0.001
Sipunculidae						1.56	0.04	0.43	0.01
Cnidaria		1.82	0.33	0.61	0.02	0.78	0.06	0.07	0.001
	Coelenterata UI	0.91	0.25	0.32	0.01	0.78	0.06	0.07	0.001
	Sertularella turgida	0.91	0.08	0.30	0.003				
Mollusca		9.09	0.33	19.38	1.80	33.59	1.20	22.50	10.47
Gastropoda	*Crepidula* sp.					0.78	0.04	0.05	0.001
	Amphisa versicolor					0.78	0.02	0.02	0.0004
	Opistobranchia UI	0.91	0.08	10.11	0.09				
	Nudibranchia UI					3.13	0.10	0.10	0.01
	Bulla gouldiana					0.78	0.02	0.01	0.0003
	Aplisia sp.					0.78	0.02	0.004	0.0002
	Doto sp.					0.78	0.02	0.01	0.0003
Bivalvia	Naticidae UI					1.56	0.04	2.51	0.05
	Tagelus sp.	0.91	0.03	2.31	0.02	3.91	0.10	2.12	0.11
	Tagelus californicus					4.69	0.14	4.57	0.29
	Tagelus subteres					0.78	0.02	0.59	0.01
	Solen rosaceus	0.91	0.03	4.31	0.04	10.94	0.35	8.99	1.34
	Laevicardium substriatum	1.82	0.06	2.62	0.05				
	Lasaea sp.					0.78	0.02	0.004	0.0002
	Lima hemphilli					1.56	0.04	0.12	0.003
	Bivalve remains	4.55	0.14	0.03		8.59	0.29	3.40	0.42
Polychaeta		1.82	0.69	2.99	0.07	4.69	0.39	0.50	0.05
	Orbiinidae UI	1.82	0.69	2.99	0.07	4.69	0.39	0.50	0.05
Mysidea	*Lycomisis* sp.	17.27	5.69	2.54	1.43	7.03	5.44	0.39	0.54

Table 1. Continued.

Taxon	Prey	*Paralabrax clathratus*				*Paralabrax nebulifer*			
		%F	%N	%W	%IRI	%F	%N	%W	%IRI
Cumacea	Cumacea UI					7.03	0.21	0.06	0.03
Decapoda		30.91	3.05	38.74	12.98	42.97	4.86	21.60	14.96
Caridea	Caridea UI	4.55	0.25	0.94	0.05	3.91	0.12	0.34	0.02
	Hippolite californiensis	10.00	0.89	2.22	0.31	5.47	0.25	0.24	0.04
	Alpheus sp.	0.91	0.03	2.52	0.02	2.34	0.06	0.27	0.01
	Caridean larvae	6.36	0.22	0.10	0.02	2.34	0.08	0.03	0.003
Anomura	Anomura UI	2.73	0.14	0.85	0.03	1.56	0.10	0.13	0.005
Brachyura	*Portunus xantusii xantusii*					3.91	0.12	2.75	0.15
	Callinectes arcuatus	1.82	0.08	12.85	0.24				
	Majidae UI	0.00	0.00	0.00		1.56	0.04	0.09	0.003
	Pyromaia tuberculata tuberculata	0.91	0.03	1.75	0.02	10.16	0.45	4.93	0.72
	Scyra acutifrons					3.13	0.12	2.70	0.12
	Pugettia dalli					0.78	0.02	0.30	0.003
	Pugettia producta					0.78	0.02	0.10	0.001
	Hemigrapsus oregonensis					1.56	0.06	0.87	0.02
	H. nudus	0.91	0.03	0.28	0.003				
	L. leucomanus					1.56	0.08	1.10	0.02
	L. leucomanus heathii					0.78	0.02	0.41	0.004
	Cancer sp.	0.91	0.03	5.26	0.05				
	C. antenarius					0.78	0.02	1.16	0.01
	P. pubecens					0.78	0.02	0.13	0.002
	Brachyuran remains	5.45	1.30	2.42	0.20	15.63	3.31	6.04	1.92
Gammaridea		75.45	84.20	20.57	79.41	49.22	74.02	4.61	50.91
	Gammaridea sp 17	12.73	7.80	2.93	1.37	11.72	2.05	0.19	0.35
	Gammaridea sp 18					0.78	0.08	0.01	0.001
	Elasmopus sp.	9.09	6.08	1.40	0.68	0.78	0.08	0.01	0.001
	Maera sp.					0.78	0.02	0.01	0.0003
	Corophiidae UI					0.78	0.19	0.08	0.003
	Corophium acherusicum	39.09	29.73	7.08	14.46	20.31	27.74	1.28	7.76

Table 1. Continued.

		Paralabrax clathratus				*Paralabrax nebulifer*			
Taxon	Prey	%F	%N	%W	%IRI	%F	%N	%W	%IRI
	Erichtonius sp.	8.18	3.41	0.42	0.31	19.53	23.79	1.78	6.57
	Hyale sp.	20.00	8.55	4.18	2.56	10.16	1.39	0.20	0.21
	Lembos sp.					1.56	0.10	0.03	0.003
	Microdeutopus sp.					0.78	0.02	0.00	0.0002
	Synchelidium sp.					1.56	0.33	0.02	0.01
	Podocerus sp.	0.91	0.03	0.02	0.0004	2.34	0.21	0.02	0.01
	Gammaridean remains	17.27	28.60	4.54	5.75	12.50	18.01	0.99	3.12
					0.18				
Caprellidea		9.09	0.69	1.28	0.18	10.16	0.46	0.28	0.10
	Caprella sp.	9.09	0.69	1.28		6.25	0.23	0.17	0.03
	Caprella californica					3.91	0.23	0.12	0.02
Isopoda		37.27	3.89	3.45	2.75	35.94	10.80	2.80	6.43
	Dinamitella dilatata					1.56	0.04	0.03	0.001
	Paracerceis cordata	3.64	0.14	0.35	0.02	7.03	0.17	0.15	0.03
	Cirolana harfordi	36.36	3.75	3.10	2.50	30.47	10.55	2.60	5.27
	Assellota UI					1.56	0.04	0.02	0.001
Echinodermata						3.13	0.10	1.64	0.07
Ophiuroidea	*Amphiodia* sp.					0.78	0.02	0.10	0.001
	Amphiodia occidentalis					0.78	0.02	0.31	0.003
	Ophiotrix spiculata					1.56	0.06	1.23	0.03
Actinopterygii		12.73	0.61	9.28	1.26	26.56	1.76	44.83	16.28
	Cynoglosidae UI					0.78	0.02	0.004	0.0002
	Atherinidae UI					2.34	0.25	0.03	0.01
	syngnatidae UI					1.56	0.04	0.04	0.002
	Ilypnus gilberti					6.25	0.21	1.63	0.15
	Gobiidae UI	4.55	0.22	5.56	0.26	2.34	0.08	0.26	0.01
	Anchoa sp.					2.34	0.08	10.77	0.33
	Fish remains	8.18	0.39	3.73	0.34	11.72	1.08	32.10	5.12

imum frequency (29.8%) at 80 mm; in barred sand bass the minimum size class was 60 mm and maximum 160 mm, maximum frequency (28.1%) was observed in the 100 mm size class (Figure 2b). The size of bass groups had homogeneous variances ($F = 2.6$, $P > 0.01$), and MANOVA test revealed significant differences between seasons ($F = 59.6$, $P < 0.01$) and between species ($F = 228.5$, $P < 0.01$), no interaction among species and seasons were detected ($F = 181.7$, $P < 0.01$). Post hoc comparison with Duncan's multiple range test, showed no differences between kelp bass and barred sand bass winter groups only.

General Food Habits

Kelp bass diet consisted of ten prey groups: eelgrass fragments, cnidarians, mollusks, polychaetes, mysids, decapods, gammarids, caprellids, isopods, and fishes. Gammarids were the most important food item in the kelp bass diet, with the highest value of IRI (79.4%), and decapods ranked second with 12.9% (Table 1). Highest values of frequency of occurrence (75.4%) and numeric percentage (84.2%) were found for gammarids also. The highest values of weight percentage were the decapods (38.7%). The principal gammarid species was *Corophium acherusicum* (Table 1).

Besides the prey groups mentioned for kelp bass, the diet of barred sand bass were sipunculids, cumaceans, and echinoderms. Gammarids were the dominant food item, with 50.9% of IRI, fish ranked second with 1.2% (Table 1). Gammarids had the highest frequency of occurrence (49.2%) and numeric percentage (74.0%). Fishes showed the highest weight percentage (44.8%). Gammarids were dominated by genus *Erichtonius* sp., and food fishes were unidentified teleosts and the anchovy, *Anchoa* sp. (Table 1).

Seasonal Variation of Diet

In kelp bass diet, the dominance of gammarids was similar in summer and winter, although their importance slightly diminished from 83.9 to 74.9% of total IRI. This can be attributed to the decrease in percent weight of gammarids from 46.6% in summer to 9.5% in winter. A frequency occurrence increase from summer to winter was observed in eelgrass fragments (0.8 to 7.1%) and fishes (1.6 to 12.2%). Mysids and caprellids were present in summer only. Weight percent was dominated by gammarids in summer (46.6%) (Figure 3a) and decapods in winter (48.8%; Figure 3a,b). Significant differences in the numerical abundance of prey groups between summer and winter diet ($G = 168.1$, $P < 0.05$) were found.

In barred sand bass diet, an importance increase in gammarids from summer (40.0% IRI) to winter (88.4% IRI) was observed (Figure 3c,d). This change was related to the increase of frequency of occurrence (43.8 to 65.6%), numeric (65.2 to 95.0%) and weight (2.5 to 49.8%) percentages from summer to winter (Figure 3c,d). Decapods diminished in importance from summer (18.3% IRI) to winter (5.0% IRI), with a seasonal diminution of numeric percentage (6.5% in summer to 0.90% in winter). In summer, fishes (46.2%), mollusks (23.4%) and decapods (21.8%) dominated by weight, and gammarids during winter (Figure 3c,d). The G-statistic revealed significant differences in the numerical abundance of prey groups between seasons ($G = 335.8$, $P < 0.05$). Mean feeding intensity in kelp bass increased from 1.1 (±1.0 SD) in summer to 2.0 (±5.6 SD) in winter (Figure

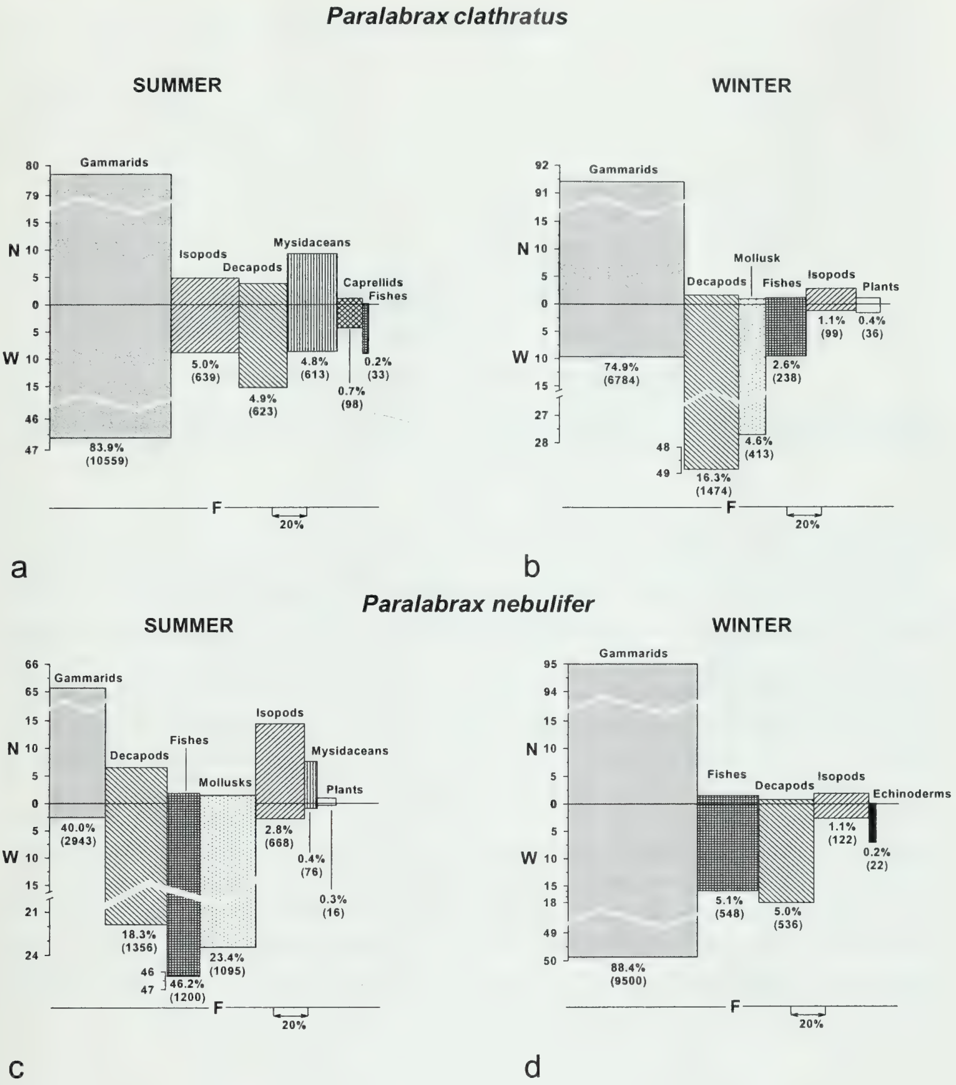

Fig. 3. Relative importance by percent number (N), percent weight (W) and percent frequency occurrence (F) of principal prey of kelp bass during summer (a), and winter (b) and barred sand bass during summer (c) and winter (d) from Punta Banda estuary. Below bars: IRI percentage and IRI values (parenthesis).

4). Significant differences in feeding intensity between seasons ($H = 145.7$, $P < 0.01$) were found. In barred sand bass, a decrease of feeding intensity from 1.0 (±1.6 SD) in summer to 0.6 (±0.4 SD) in winter (Figure 4) was observed. Significant differences were observed in feeding intensity between seasons ($H = 6.1$, $P < 0.05$).

In kelp bass, a significant ($\chi^2 = 15.4$, $P < 0.01$) increase in empty stomachs was found from summer (5.1%) to winter (29.4%) (Figure 5). In barred sand bass, no differences ($\chi^2 = 0.8$, $P < 0.1$) was observed in empty stomachs (4.0% summer, 5.8% winter; Figure 5).

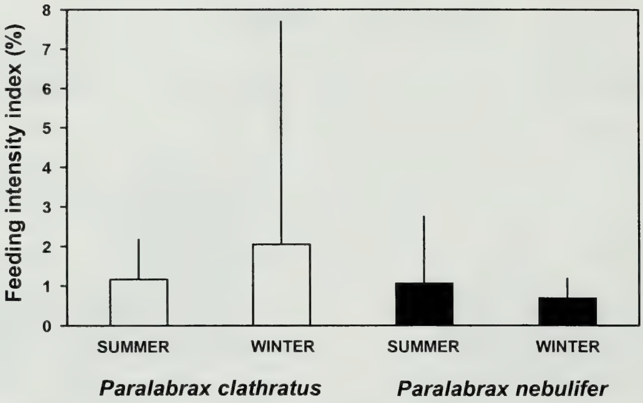

Fig. 4. Seasonal changes in feeding intensity index by kelp bass and barred sand bass from Punta Banda estuary (error bars are standard deviation).

Diet Breath and Overlap

In both kelp bass and barred sand bass, the numeric diet breadth was highest during summer (0.038 and 0.12) and diminished in winter (0.031 and 0.013; Figure 6). Homogeneity of variances between summer and winter groups of kelp bass was accepted ($F = 0.7$, $P < 0.05$), and ANOVA showed that numeric diet breath was significantly different between seasons ($F = 7.0$, $P < 0.01$). Homogeneity of variances was not accepted in winter groups of barred sand bass ($F = 1558.4$, $P < 0.01$), and Kruskal-Wallis ANOVA showed that numeric diet breath was significantly different between seasons ($H = 1567.8$, $P < 0.01$).

With respect to diet weight breadth for kelp bass, values were 0.31 in summer, and 0.27 in winter. In barred sand bass, and increase of weight diet breadth was observed from summer (0.18) to winter (0.26; Figure 6). Variances were homogeneous of weight diet breadth between seasons for both species (kelp bass $F = 2.4$, $P > 0.05$; barred sand bass $F = 0.9$, $P > 0.05$). Weight diet breadth of both species was significantly different between seasons (kelp bass: $F = 107.2$, $P < 0.01$; barred sand bass: $F = 702.6$, $P < 0.01$).

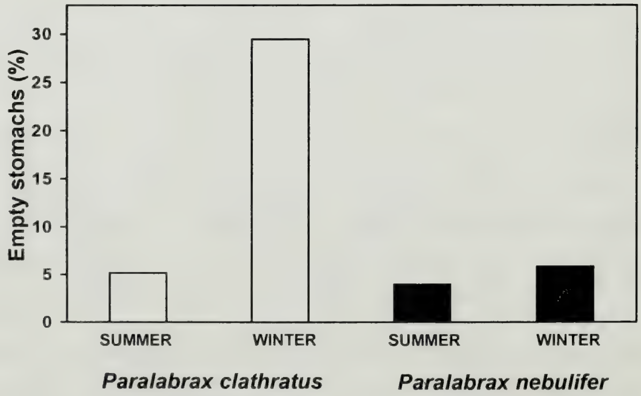

Fig. 5. Seasonal changes in vacuity values determined by kelp bass and barred sand bass from Punta Banda estuary.

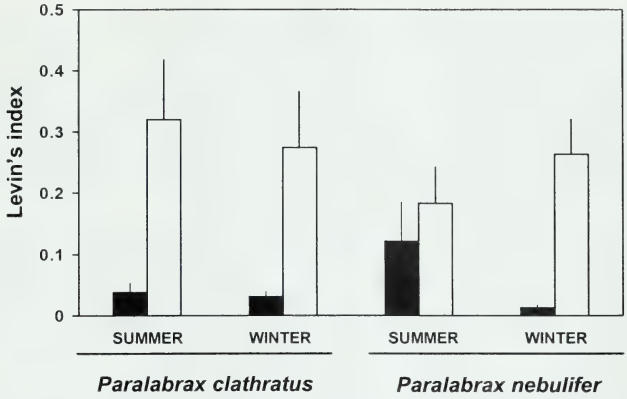

Fig. 6. Seasonal changes in numeric ■ and weight ☐ diet breath for kelp bass and barred sand bass from Punta Banda estuary (error bars are 95% bootstrap confidence intervals).

Dietary overlap between kelp bass and barred sand bass were relatively low (<0.60), although increased from summer to winter for both numeric (0.44 summer, 0.49 winter) and weight (0.17 summer, 0.24 winter) overlap (Figure 7). Variances were homogeneous between seasonal numeric (F = 2.0, P > 0.05) and weight overlap index (F = 3.84, P > 0.05). Significant differences between seasons were observed in the numeric (F = 457.7, P < 0.01), and weight overlap (F = 193.7, P < 0.01). All overlaps values (by number and weight) in the two seasons were significantly lower (P < 0.01).

Discussion

Allen et al. (1995) mentioned that kelp bass is an active predator around kelp beds and rocky reef habitats, feeding on motile organisms including fish, squid, octopi and benthic crustaceans, and concluded that a large portion of their prey were taken from the water column. These results were confirmed for adult kelp bass inhabiting the kelp beds of Todos Santos Bay, Ensenada, that fed mainly on fishes (Mendoza-Carranza, 1995). On the other hand, along the southern California coast, kelp bass feed in the mid water and suprabenthos of the kelp beds,

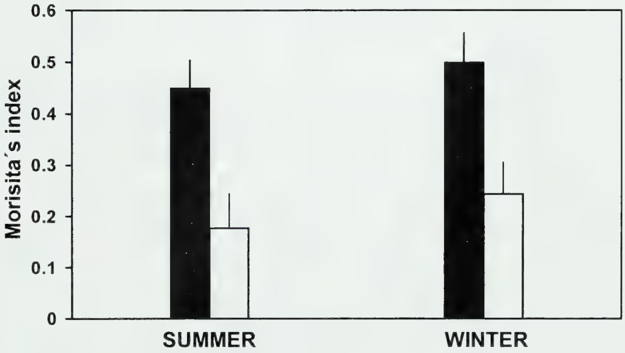

Fig. 7. Seasonal changes in numeric ■ and weight ☐ diet overlap values between kelp bass and barred sand bass from Punta Banda estuary (error bars are 95% bootstrap confidence intervals).

catching small prey as gammarids, caprellids, isopods and mysids (Ebeling and Bray (1976); Young 1963; Hobson et al. 1981). In Punta Banda estuary, kelp bass diet was similar, most prey items were small suprabenthic and benthic invertebrates (gammarids, decapods, isopods, mollusks, caprellids and mysidaceans). These preys are abundant in shallow zones of estuaries with eelgrass beds as Punta Banda Estuary (Ibarra-Obando and Escofet 1987, Ibarra-Obando and Poumian-Tapia 1991, Talley et al. 2000).

Juvenile barred sand bass are also commonly found in eelgrass beds at Alamitos Bay, California (Valle et al. 1990). In Punta Banda estuary, barred sand bass diet was dominated by gammarids, although fish, decapods and mollusks were also important. Most of these items are abundant in eelgrass beds (Ibarra-Obando and Poumian-Tapia 1991, Levin et al. 1997). Barred sand bass has been classified as a demersal fish and feed on crustaceans (Roberts et al. 1984). Our results showed that they also fed heavenly on fishes, some of which, such as pipefish, are eelgrass dependent.

The presence of eelgrass fragments in the stomach of both species underscore the importance of these plants as feeding areas. This also was observed for juvenile spotted sand bass, *Paralabrax maculatofasciatus* in Punta Banda estuary (Mendoza-Carranza 1995; Mendoza-Carranza and Rosales-Casián, 2000).

Seasonal diet pattern in both bass appeared related with changes in size. In kelp bass, this is reflected in the weight increase of prey as decapods, mollusks, and fish, mainly. Feeding intensity indicated a significant increase as a product of increase of prey size. Seasonal patterns in feeding habits for kelp bass were described by Quast (1968a). Summer diets were characterized by a wide breadth of prey item while caprellids and clupeiforms fishes dominated in winter. Love and Ebeling (1978) noted a similar pattern for kelp bass at Santa Barbara kelp beds.

Feeding habits in barred sand bass were influenced by prey availability and season (Turner et al. 1969). We believe that differences between seasonal diets are attributable to change in size; barred sand bass captured in summer were larger than in winter. This resulted in larger prey items (e.g. decapods, fishes and mollusks) being eaten. Consequently, the feeding intensity was higher in summer. Roberts et al. (1984) also found that barred sand bass change their diet as they grow. Changes in size of both bass were related to the differential use of habitats as eelgrass beds, mud or sandy bottoms in Punta Banda estuary and Todos Santos bay (Salomé-Sanchéz 1993; Rosales-Casián 1995, 1997a,b; Pintos-Terán 1994; Mendoza-Carranza 1995).

In Punta Banda estuary, a seasonal diet change of spotted sand bass has been related to differences in available prey over time, as well as the trophic flexibility of species (Mendoza-Carranza and Rosales-Casián, 2000). These assertions seem to also be applicable for kelp bass and barred sand bass.

The interpretation of diet breadth is highly dependent on the variable used to calculate the indices (Wallace 1981; Hall et al. 1990). A numeric diet breadth measurement was influenced strongly by few small prey items with high numeric dominance (Labropoulou and Eleftheriou 1997). In this case, the gammarids cause low values of niche breadth. On the other hand, biomass tends to overemphasize some large prey items (Labropoulou and Eleftheriou 1997); contrary to this, we found that values of weight diet breadth were higher than the numeric diet breadth in all surveys, caused by the weight distribution among prey items. The weight distribution was more regular than numeric distribution. The small prey items were so numerous that they constituted a relatively high biomass.

Overall, the ecological niches of the three species of California basses are different (Feder et al. 1974) which results in differences in feeding habits. Despite the low values of niche overlap (<0.60), in Punta Banda estuary, kelp bass and barred sand bass presented very close trophic affinities feeding on similar prey. These trophic affinities were likely the result of the generalized morphology of two species (Roberts et al. 1984) and, the fact that both species were occupying the same habitats, mainly the eelgrass beds and adjacent areas.

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Helminths of the Bullfrog, *Rana catesbeiana* (Ranidae), in California with Revisions to the California Anuran Helminth List

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Abstract.—Thirty-one bullfrogs, *Rana catesbeiana,* from northern California were examined for helminths. Gravid individuals representing three species of Trematoda, *Glypthelmins quieta, Haematoloechus longiplexus* and *Megalodiscus temperatus;* one species of Cestoda, *Ophiotaenia magna;* and three species of Nematoda, *Cosmocercoides variabilis, Falcaustra catesbeianae* and *Oswaldocruzia pipiens* were found. Larvae representing three species of Nematoda, *Contracaecum* sp., *Eustrongylides* sp., and *Physaloptera* sp. were also found. *Rana catesbeiana* is parasitized by generalist helminths that occur in other frogs and have previously been found in *R. catesbeiana* in other parts of North America. This is the first report of *Falcaustra catesbeianae, Contracaecum* sp. and *Eustrongylides* sp. from California anurans. The helminth host list for California anurans is revised.

The bullfrog, *Rana catesbeiana,* was first described from a collection taken in the vicinity of Charleston, South Carolina (Shaw, 1802). The original range covered most of eastern North America from the mouth of the Pecos River, Texas through the Panhandles of Texas and Oklahoma, extreme western Kansas, Nebraska and Minnesota, eastward to Maine and the northern half of Florida (Wright and Wright 1995). Subsequently, the bullfrog was introduced into each of the western states as well as Mexico and British Columbia, Canada (Stebbins 1985). In California, bullfrogs were first introduced in 1896 (Heard 1904) for human food after populations of native frogs, particularly the red-legged frog, *Rana aurora,* were overharvested (Jennings and Hayes 1985). Introductions and subsequent range expansions of the bullfrog have coincided with declines of native ranid frogs in western North America which has in turn generated interest in frog population ecology and competition (Kiesecker and Blaustein 1997; Kupferberg 1997; Lawler et al. 1999). However, little attention has been given to helminths of introduced frogs. To our knowledge, there are four reports of helminths in California bullfrogs (Ingles 1936; Nicol et al. 1985; Shields 1987; Wootton et al. 1993). Helminths of the bullfrog in North America have been summarized by Andrews et al. (1992). Additional helminths are listed in Bursey and DeWolf (1998), Goldberg et al. (1998) and McAlpine and Burt (1998). The purpose of this paper is to report additional helminths of California bullfrogs and to revise the helminth list for California anurans.

Methods

Thirty-one bullfrogs collected in 1997 and 1998 from northern California were examined for helminths. All frogs were deposited in the herpetology collection of the Natural History Museum of Los Angeles County (LACM) after examination. Sixteen frogs (LACM 144342-144357) were from Upper Searsville Lake, Jasper Ridge Biological Preserve, Woodside, San Mateo County (37°30′N, 122°30′W); 15 frogs (LACM 146746-146751, 146753, 146754, 146756-146762) were from sites between Uvas and Calero Reservoirs, Santa Clara County (37°05′N, 121°45′W). The frogs were initially fixed in 10% formalin and preserved in 70% ethanol. The body cavity was opened by a longitudinal incision from throat to pelvis and the gastrointestinal tract, lungs and urinary bladder were removed. Each organ was opened and examined for helminths under a dissecting microscope. The surface of the liver and the body cavity were also searched. Nematodes were placed on a microscope slide and cleared in glycerine. A coverslip was added to the slide and the nematode was identified using a compound microscope. Cestodes and trematodes were rehydrated, stained in hematoxylin, dehydrated in a series of graded ethanols, cleared in xylene, mounted on a glass slide in Canada balsam and identified using a compound microscope.

Three similarity indices were calculated in order to compare the *R. catesbeiana* helminths from San Mateo and Santa Clara Counties. The Jaccard coefficient is based on species presence in a community and ranges from 0 (no species in common) to 1.0 (all species in common); Morisita's index considers number of species, number of individuals, and proportion of the total represented by each species and ranges from 0 (no similarity) to 1.0 (identical); percent similarity is based on species abundance and ranges from 0 (no similarity) to 100 (same species found in both communities at similar abundances) (Brower et al. 1997).

Results

Gravid individuals of three species of Trematoda, *Glypthelmins quieta* (Stafford, 1900), *Haematoloechus longiplexus* Stafford 1902, *Megalodiscus temperatus* (Stafford, 1905); one species of Cestoda, *Ophiotaenia magna* Hannum, 1925; and three species of Nematoda, *Cosmocercoides variabilis* (Harwood, 1930), *Falcaustra catesbeianae* Walton, 1929, *Oswaldocruzia pipiens* Walton, 1929, were found. Larvae representing three species of Nematoda, *Contracaecum* sp., *Eustrongylides* sp., and *Physaloptera* sp. were also found. Prevalence (percent of sample infected) and mean intensity (mean number of helminths per infected frog ± 1 SD) by helminth species are given in Table 1.

The helminths exhibited site specific infections: *Glypthelmins quieta, Ophiotaenia magna, Cosmocercoides variabilis* and *Oswaldocruzia pipiens* were found in the small intestine, *Megalodiscus temperatus* and *Falcaustra catesbeianae* in the large intestine, and *Haematoloechus longiplexus* in the lungs. Larvae of *Contracaecum* sp., and *Eustrongylides* sp. were found in cysts within the body cavity and most often attached to the mesenteries; larvae of *Physaloptera* sp. were found within the lumen of the stomach. In no cases did two parasite species occupy the same site in a single host.

Selected helminths were deposited in the United States National Parasite Collection, USNPC, Beltsville, Maryland 20705 as: *Glypthelmins quieta* (91248),

Table 1. Prevalence (as %), mean intensity ± 1 SD, and range for helminths from *Rana catesbeiana* from San Mateo and Santa Clara Counties, California; n = number of hosts examined.

	San Mateo County n = 16 (SVL = 109 mm ± 18 mm SD)			Santa Clara County n = 15 (SVL = 153 mm ± 17 mm SD)		
	Prevalence	Mean intensity	Range	Prevalence	Mean intensity	Range
Glypthelmins quieta	6	1	—	7	12	—
Haematoloechus longiplexus	56	4.8 ± 5.2	1–17	49	3.7 ± 5.1	1–17
Megalodiscus temperatus	56	3.2 ± 3.5	1–12	—	—	—
Ophiotaenia magna	—	—	—	20	1 ± 0	—
Cosmocercoides variabilis	—	—	—	7	2	—
Falcaustra catesbeianae	50	4.3 ± 3.6	1–12	—	—	—
Oswaldocruzia pipiens	—	—	—	7	6	—
Contracaecum sp. (larvae)	38	2.3 ± 1.4	1–5	—	—	—
Eustrongylides sp. (larvae)	—	—	—	20	1 ± 0	—
Physaloptera sp. (larvae)	—	—	—	20	2.7 ± 1.5	1–4

Haematoloechus longiplexus (91244), *Megalodiscus temperatus* (91245), *Ophiotaenia magna* (91249), *Cosmocercoides variabilis* (91250), *Falcaustra catesbeianae* (91246), *Oswaldocruzia pipiens* (91251), *Contracaecum* sp. (91247), *Eustrongylides* sp. (91252), *Physaloptera* sp. (91253).

Discussion

All helminths found in this study have previously been reported from *Rana catesbeiana* in other parts of its range as well as from other ranids (Dyer 1991; Andrews et al. 1992). However, this is the first report of *Falcaustra catesbeianae, Contracaecum* sp. (larvae) and *Eustrongylides* sp. (larvae) from California anurans (Table 2).

Glypthelmins quieta, Haematoloechus longiplexus and *Megalodiscus temperatus* are common trematode parasites of North American frogs (Smyth and Smyth 1980). These three species require a molluscan first intermediate host. After release from the molluscan host, cercariae of *Glypthelmins quieta* and *Megalodiscus temperatus* penetrate the skin of anurans and encyst beneath the epidermis. Infection occurs when a frog ingests its own cast skin after molting. Cercariae of *Haematoloechus longiplexus* penetrate and encyst in naiads of dragonflies; infection occurs through ingestion of dragonflies (Smyth and Smyth 1980). The host list for *Glypthelmins quieta* includes five genera of anurans, *Acris, Bufo, Hyla, Pseudacris* and *Rana;* for *Haematoloechus longiplexus,* two genera, *Bufo* and *Rana;* for *Megalodiscus temperatus,* four genera of anurans, *Bufo, Hyla, Pseudacris,* and *Rana,* five genera of Caudata, *Ambystoma, Amphiuma, Desmognathus, Notophthalmus* and *Pseudotriton,* and one genus of Serpentes, *Coluber* (Parker 1941; Catalano et al. 1982; Prudhoe and Bray 1982).

There is some confusion surrounding the identity of North American ranid proteocephalid cestodes; four have been reported, namely, *Ophiotaenia magna, Ophiotaenia saphena* Osler, 1931, *Crepidobothrium olor* Ingles, 1936 and *Ophiotaenia gracilis* Jones, Cheng and Gillespie, 1958. Brooks (1978) discussed morphological characteristics of these species and concluded no significant morpho-

Table 2. Helminths of California Anura.

Helminth	County	Reference
Trematoda		
Alaria mustelae Bosma, 1931		
Hyla regilla	Santa Clara	Johnson et al. 1999
Alaria sp. (mesocercaria)		
Hyla cadaverina	Riverside	Goldberg and Bursey 2001a
Hyla regilla	Santa Clara	Goldberg and Bursey 2001b
Brachycoelium lynchi Ingles, 1935		
Rana aurora	Siskiyou	Ingles 1936
Cephalogonimus americanus Stafford, 1902		
= *Cephalogonimus brevicirrus* Ingles, 1932		
= *Cephalogonimus retusus* of Walton, 1938		
Rana aurora	Kern	Ingles 1932a
Rana aurora	Kern	Ingles 1936
Clinostomum sp. (metacercaria)		
Hyla regilla	Humboldt, Santa Clara	Goldberg and Bursey 2001a
Rana aurora	not given	Ingles 1936
Rana boylii	not given	Ingles 1936
Fibricola sp. (metacercaria)		
Hyla cadaverina	Los Angeles	Goldberg and Bursey 2001a
Glypthelmins sp.		
Bufo boreas	Los Angeles	Koller and Gaudin 1977
Glypthelmins quieta (Stafford, 1900) Stafford, 1905		
= *Distomum quietum* Stafford, 1900		
= *Margeana californiensis* Cort, 1919		
= *Glypthelmins californiensis* (Cort, 1919) Miller, 1930		
= *Glypthelmins subtropica* Harwood, 1932		
Rana aurora referred by Sullivan, 1976	San Francisco	Cort 1919

Table 2. Continued.

Helminth	County	Reference
Rana aurora referred by Sullivan, 1976	San Diego, Butte	Ingles 1936
Rana boylii referred by Sullivan, 1976	Butte	Ingles 1936
Rana boylii referred by Sullivan, 1976	Marin, Sonoma	Lehmann 1960
Rana catesbeiana	San Mateo, Santa Clara	this study
Glypthelmins shastai Ingles, 1935		
Bufo boreas	Shasta	Ingles 1936
Gorgoderina sp.		
Bufo boreas	Siskyou	Ingles 1936
Hyla cadaverina	Los Angeles, Orange	Goldberg and Bursey 2001a
Rana aurora	Kern	Ingles 1932a
Gorgoderina aurora Ingles, 1935		
Rana aurora	San Francisco, San Joaquin	Ingles 1936
Gorgoderina multilobata Ingles and Langston, 1933		
Rana aurora	Los Angeles	Ingles and Langston 1933
Rana aurora	Butte	Ingles 1936
Rana boylii	Butte	Ingles and Langston 1933
Rana boylii	Butte	Ingles 1936
Rana pretiosa	Butte	Ingles 1936
Gyrodactylus catesbeianae Wootton, Ryan, Demaree and Critchfield, 1993		
Rana catesbeiana (tadpoles)	Glenn	Wootton, et al. 1993
Haematoloechus sp.		
Rana aurora	Kern	Ingles 1932a
Rana aurora	Marin, Sonoma	Lehmann 1960
Rana boylii	Marin, Sonoma	Lehmann 1960
Haematoloechus complexus (Seely, 1906) Yamaguti, 1958		
= *Pneumonoeces complexus* Seely, 1906		
= *Haematoloechus confusus* Ingles, 1932		
= *Haematoloechus oxyorchis* Ingles, 1932		

Table 2. Continued.

Helminth	County	Reference
= *Ostiolum oxyorchis* (Ingles, 1932) Ingles, 1936		
Rana aurora	San Francisco	Ingles 1932b
Rana aurora	Los Angeles	Ingles 1933
Rana aurora	San Francisco	Ingles 1936
Haematoloechus kernensis Ingles, 1932		
= *Haematoloechus tumidus* Ingles, 1932		
Bufo boreas	San Bernardino	Goldberg et al. 1999
Rana aurora	Kern	Ingles 1932b
Rana aurora	Kern	Ingles 1936
Haematoloechus longiplexus Stafford, 1902		
Rana catesbeiana	Ventura	Shields 1987
Rana catesbeiana	San Mateo, Santa Clara	this study
Haematoloechus variplexus Stafford, 1902		
= *Haematoloechus buttensis* Ingles, 1936		
Rana boylii	Butte	Ingles 1936
Halipegus aspina Ingles, 1932		
Rana boylii	Butte	Ingles 1936
Rana boylii	Marin, Sonoma	Lehmann 1960
Langeronia burseyi Dailey and Goldberg, 2000		
Hyla cadaverina	Orange	Dailey and Goldberg 2000
Hyla cadaverina	Orange	Goldberg and Bursey 2001a
Levinseniella ophidea Nicol, Demaree and Wootton, 1985		
Rana catesbeiana	Lassen	Nicol et al. 1985
Megalodiscus microphagus Ingles, 1936		
Bufo boreas	Shasta	Ingles 1936
Megalodiscus temperatus (Stafford, 1905) Yamaguti, 1958		
Rana boylii	Marin, Sonoma	Lehmann 1960

Table 2. Continued.

Helminth	County	Reference
Rana catesbeiana	Butte	Ingles 1936
Rana catesbeiana	San Mateo	this study
Ribeiroia sp. (metacercaria)		
Bufo boreas	Santa Clara	Johnson et al. 1999
Hyla regilla	Santa Clara	Johnson et al. 1999
Rana catesbeiana	Santa Clara	Johnson et al. 1999
Cestoda		
Cylindrotaenia americana Jewell, 1916		
Bufo canorus	Mariposa	Walton 1941
Distoichometra bufonis Dickey, 1921		
Bufo boreas referred by Goldberg et al., 1999	Los Angeles	Koller and Gaudin 1977
Bufo boreas	Los Angeles, San Bernardino	Goldberg et al. 1999
Hyla cadaverina	Riverside	Goldberg and Bursey 2001a
Hyla regilla referred by Goldberg et al., 1999	Los Angeles	Koller and Gaudin 1977
Hyla regilla	Santa Clara	Goldberg and Bursey 2001b
Ophiotaenia magna Hannum, 1925		
= *Ophiotaenia saphena* Osler, 1931		
= *Crepidobothrium olor* Ingles, 1936		
= *Ophiotaenia gracilis* Jones, Cheng and Gillespie, 1958		
Rana aurora	Alameda	Ingles 1936
Rana catesbeiana	Santa Clara	this paper
Unidentified dilepinid		
Rana boylii	Siskiyou	Ingles 1936
Nematoda		
Aplectana itzocanensis Bravo Hollis, 1943		
Bufo boreas	Orange, Riverside, San Bernardino	Goldberg et al. 1999
Contracaecum sp. (larvae)		
Rana catesbeiana	San Mateo	this study

Table 2. Continued.

Helminth	County	Reference
Cosmocercoides variabilis (Harwood, 1930) Travassos, 1931		
= *Cosmocerca dukae* Holl, 1928 (in part)		
= *Oxysomatium americana* Walton, 1929		
= *Oxysomatium variabilis* Harwood, 1930		
Bufo boreas referred by Goldberg et al., 1999	Shasta	Ingles 1936
Bufo boreas referred by Goldberg et al., 1999	Los Angeles	Koller and Gaudin 1977
Bufo boreas	Riverside	Goldberg et al. 1999
Bufo canorus	Mariposa	Walton 1941
Hyla regilla referred by Goldberg et al., 1999	Los Angeles	Koller and Gaudin 1977
Rana aurora referred by Goldberg et al., 1999	Butte	Ingles 1936
Rana catesbeiana	Kern	Ingles 1936
Rana catesbeiana	Santa Clara	this study
Eustrongylides sp. (larvae)		
Rana catesbeiana	Santa Clara	this study
Falcaustra catesbeianae Walton, 1929		
Rana catesbeiana	San Mateo	this study
Falcaustra inglisi (Anderson, 1964) Baker, 1980		
= *Oxysomatium inglisi* Anderson, 1964		
Bufo boreas	Los Angeles	Goldberg et al. 1999
Falcaustra pretiosa (Ingles, 1935) Freitas and Lent, 1941		
= *Spironoura pretiosa* Ingles, 1935		
Bufo boreas	Inyo	Walton 1941
Rana aurora	Santa Clara	Walton 1941
Rana boylii	Tuolumne	Walton 1941
Rana pretiosa	Plumas	Ingles 1936
Falcaustra ranae (Walton, 1941) Chabaud and Golvan, 1957		
= *Spironoura ranae* Walton, 1941		
Rana boylii	Mariposa	Walton 1941

Table 2. Continued.

Helminth	County	Reference
Oswaldocruzia pipiens Walton, 1929		
= *Oswaldocruzia waltoni* Ingles, 1935		
Bufo boreas	Butte, Kern, San Diego	Ingles 1936
Bufo boreas referred by Goldberg et al., 1999	Los Angeles	Koller and Gaudin 1977
Bufo boreas	Los Angeles, Riverside	Goldberg et al. 1999
Hyla regilla referred by Goldberg et al., 1999	Los Angeles	Koller and Gaudin 1977
Hyla regilla	Santa Clara, Imperial, Los Angeles, Orange, Riverside	Goldberg and Bursey 2001b
Rana aurora	Butte, Kern, San Diego	Ingles 1936
Rana catesbeiana	Santa Clara	this study
Physaloptera sp. (larvae)		
Bufo boreas	Orange	Goldberg et al. 1999
Hyla cadaverina	Los Angeles, Orange	Goldberg and Bursey 2001a
Hyla regilla	Orange	Goldberg and Bursey 2001b
Rana catesbeiana	Santa Clara	this study
Rhabidas sp.		
Bufo boreas	not given	Ingles 1936
Bufa boreas	Los Angeles	Koller and Gaudin 1977
Hyla regilla	Los Angeles	Koller and Gaudin 1977
Rana boylii	not given	Ingles 1936
Rana boylii	Marin, Sonoma	Lehmann 1960
Rhabdias americanus Baker, 1978		
Bufo boreas	San Bernardino	Goldberg et al. 1999
Rhabdias joaquinensis Ingles, 1935		
Rana aurora	San Joaquin	Ingles 1936
Rhabdias ranae Walton, 1929		
Hyla cadaverina	Los Angeles, Riverside	Goldberg and Bursey 2001a
Hyla regilla	Orange, Riverside	Goldberg and Bursey 2001b

logical differences existed between them. He did not place them in synonymy but assigned all to *Proteocephalus.* More recently, Schmidt (1986) assigned these species to *Ophiotaenia.* Since it is not possible to distinguish these four species and because we can find no difference between individuals collected in California and Ohio (see Bursey and DeWolf 1998), we have assigned our specimens to *Ophiotaenia magna* which has priority. In addition, we have referred all California ranid proteocephalids to *Ophiotaenia magna* (Table 2).

Cosmocercoides variabilis, Falcaustra catesbeianae and *Oswaldocruzia pipiens* are common nematode parasites of North American frogs (Baker 1987). Like the trematodes found in this study, these nematodes are generalists, i.e., found in more than one host. However, some uncertainty exists for hosts of North American species of *Cosmocercoides. Cosmocercoides variabilis,* originally described as *Oxysomatium variabilis* by Harwood (1930) from *Bufo valliceps* collected at Houston, Texas was considered a synonym of the molluscan parasite *Cosmocercoides dukae* by Ogren (1953, 1959) who presumed that amphibians acquired *C. dukae* infections by ingesting infected molluscs. *Cosmocercoides dukae* was first described as *Cosmocerca dukae* by Holl (1928) from *Triturus viridescens* collected in North Carolina. Wilkie (1930) established the genus *Cosmocercoides,* and Travassos (1931) included both *C. dukae* and *C. variabilis* in his monograph on the Cosmocercidae. Vanderburgh and Anderson (1987) demonstrated that these two species of *Cosmocercoides* are distinct. The major difference between the two species is the number of rosette papillae of the male; *C. dukae* with 12 pairs; *C. variabilis* with 14 to 20. Specimens collected in this study exhibited 16–18 rosette papillae. The host list for *C. variabilis* includes the five genera of anurans, *Bufo, Gastrophryne, Hyla, Pseudacris, Rana,* two genera of Caudata, *Ambystoma, Notophthalmus;* two genera of lizards, *Scincella, Ophisaurus;* three of snakes, *Heterodon, Micrurus, Storeria;* and one of tortoises, *Terrapene* (Baker 1987). Ingles (1936) reported *C. dukae* from *Taricha torosa, Rana aurora* and *Bufo boreas* from California but illustrated 16 papillae and for this reason we have referred his specimens to *Cosmocercoides variabilis* (Table 2). *Falcaustra catesbeianae* has been reported from four genera of Anura, namely, *Gastrophryne, Hyla, Pseudacris, Rana,* and two genera of Caudata, *Siren* and *Typhlotriton* (Baker 1987). All North American specimens of the genus *Oswaldocruzia* have been referred to *O. pipiens* by Baker (1977). This species is widely distributed in North America and has been reported from six genera of anurans, *Acris, Bufo, Hyla, Pseudacris, Rana, Scaphiopus;* three of Caudata, *Desmognathus, Eurycea, Plethodon,* seven genera of lizards, *Anolis, Eumeces, Elgaria, Gerrhonotus, Heloderma, Sceloporus, Scincella;* and one of tortoises, *Terrapene* (Baker 1987; Goldberg and Bursey 1991).

Three species of nematodes not reaching maturity in frogs were present: *Contracaecum* sp., *Eustrongylides* sp. and *Physaloptera* sp. Species of these genera require intermediate hosts: *Contracaecum,* aquatic invertebrates; *Eustrongylides,* aquatic oligochaetes; *Physaloptera,* terrestrial insects (Anderson 2000). The definitive hosts of species of *Contracaecum* are piscivorous birds and aquatic mammals, species of *Eustrongylides* are limited to piscivorous birds, and species of *Physaloptera* parasitize mammals, birds and reptiles (Anderson 2000). Because individuals of *Contracaecum* and *Eustrongylides* were found in cysts, the possibility of *Rana catesbeiana* as a paratenic host must be considered. The absence of *Physaloptera* in cysts suggests that they are taken with insect prey but cannot establish infection and are soon excreted.

Interestingly, of the ten species of helminths found in this study, only two trematodes, *Glypthelmins quieta* and *Haematoloechus longiplexus* were found at both locations of bullfrog collections. The 16 bullfrogs from San Mateo harbored 94 individuals representing 5 helminth species; 15 bullfrogs from Santa Clara harbored 67 individuals representing seven helminth species. The calculated results for Jaccard coefficient, Morisita's index and percent similarity were 0.2, 0.7, 47.9, respectively, indicating that the helminth communities harbored by the two bullfrog populations were not similar in structure. Other studies of California anurans (see Koller and Gaudin 1977; Goldberg and Bursey 2001a, 2001b) from multiple localities have reported similar results, i.e., spotty distribution of helminths for a particular host species.

The anuran helminths listed in Table 1 are generalists in that they are capable of infecting a number of hosts. Thus, it is possible that a particular host is unimportant; infection in a particular host may fluctuate from location to location, but the helminth population maintains an overall presence. Given the earlier introduction of the bullfrog to California and the later helminthological surveys (Table 2), it is not possible to determine whether bullfrogs acquired these helminths in California or transported them into the state. Neither is it possible to gauge the breadth of helminth infection for California anurans because only 8 (35%) of the 23 species of anurans known to occur in California (Stebbins 1985) have been examined for helminths. Examination of additional California anuran species must occur before the helminth community of these hosts can be assessed.

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New Records of Mammals on Small Islands in the Central Gulf of California, México

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The rich biota of islands in the Gulf of California has attracted the efforts of naturalists and research biologists for nearly a century (Case and Cody 1983). Mammals are among the better-studied groups and have been the focus of biogeographical and evolutionary research (e.g., Burt 1932; Huey 1964; Banks 1967; Lawlor 1971, 1983). Much of this work focused on fauna of large islands in the southern Gulf and Midriff region (e.g., Vaughan and Schwartz 1960; Gill 1981; Smith 1992), whereas less is known of the distribution of mammals on the dozens of small islands that surround the Baja peninsula. These small islands may be particularly important for studies of island biogeography because island area strongly influences resource availability and the probability of extinction and colonization of insular populations (MacArthur and Wilson 1967; Whittaker 1998). Here, I provide new records of the distribution of mammals on a series of small islands in the central Gulf of California. These data were collected as part of a larger research effort aimed at understanding the dynamics of island food webs (Polis and Hurd 1996; Polis et al. 1997; Stapp et al. 1999).

Between 1997 and 2000, I surveyed for the presence of rodents at 27 sites on 18 different islands in the vicinity of Bahía de los Angeles, Baja California, México (28°55′ N latitude, 113°30′ W longitude), as well as in 14 locations on the adjacent peninsula within a 30-km radius of the town of Bahía de los Angeles. The islands are extremely rocky and, except for a few perennials (*Atriplex barclayana, Opuntia* spp., *Viscainoa geniculata, Pachycereus pringlei*), have little vegetation. Sherman live traps were set in rectangular grids consisting of 24–54 traps, with one side of the grid near shore and extending inland for 125–200 m. On smaller islands or those whose terrain limited access (e.g., Mitlán and Blanca), traps were set in pairs of transects originating at the shore. Near-shore traps were usually set in coastal vegetation (*Salicornia subterminalis, Sueda moquinii, Frankenia palmeri*) associated with dunes or beach cobble, which then graded into more gravelly and rocky soils and desert scrub vegetation farther inland. Several islands, including those used by roosting and nesting seabirds, however, were essentially piles of bare rock and had little permanent vegetation.

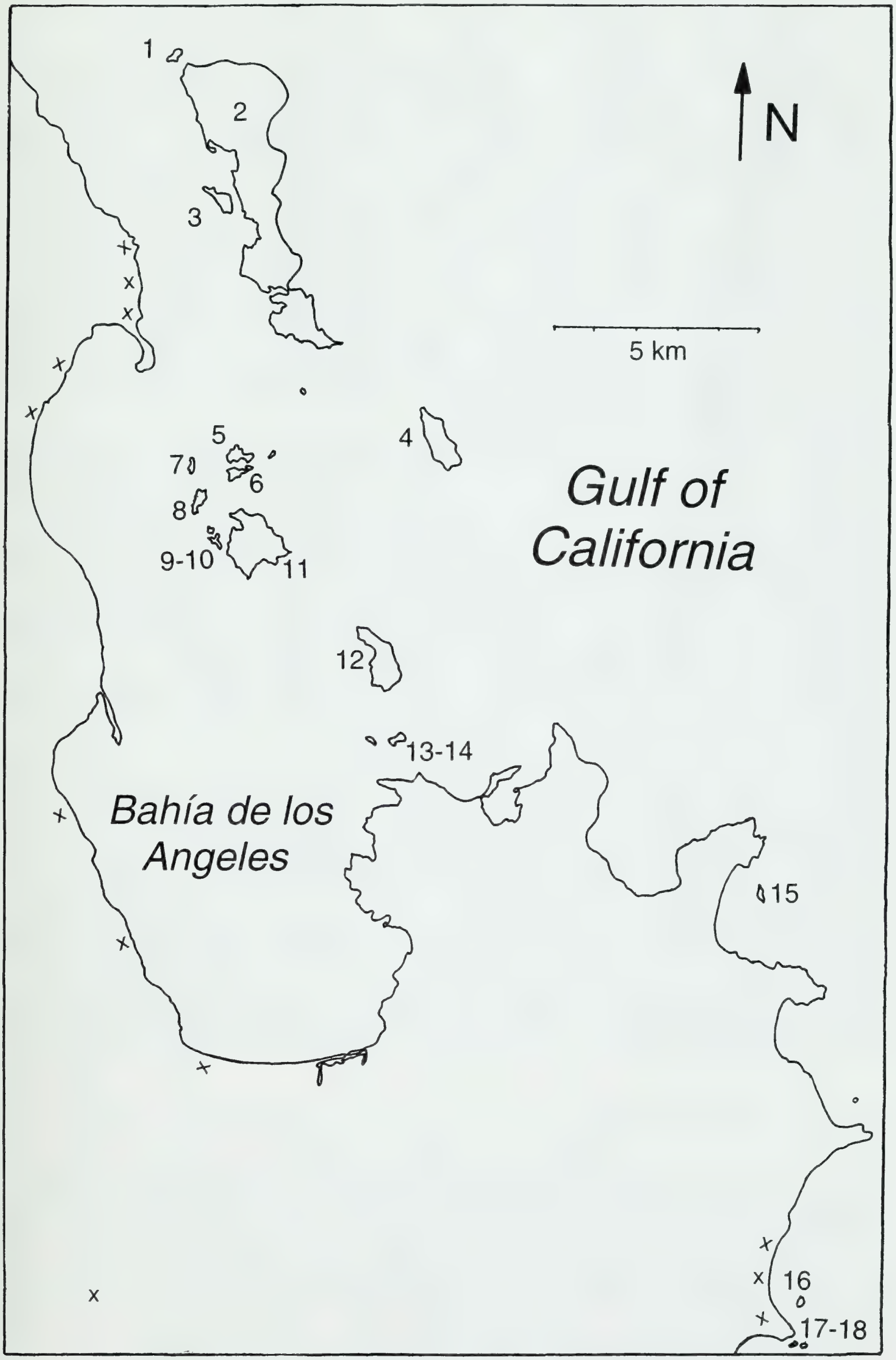
Trapping sessions typically lasted 2 or 3 consecutive nights. Traps were baited with peanut butter and oats and closed during the day to reduce mortality from heat and ants. I weighed and measured all rodents captured, and marked each with an ear-tag or Sharpie® permanent marker before releasing it at its capture location. I visited island and mainland sites during 11 separate trips to the region between 1997 and 2000.

Twelve species (*Chaetodipus baileyi, C. spinatus, C. arenarius, C. formosus, Perognathus longimembris, Dipodomys merriami, Neotoma lepida, Peromyscus*

Table 1. Morphological measurements of adult *Peromyscus* and *Chaetodipus* in the central Gulf of California, México, taken from live individuals. Values are means, with 95% confidence intervals in parentheses. Note overlap in confidence intervals between mainland and island populations of *P. maniculatus* and *C. baileyi,* and the lack of significant overlap with other species.

Species	N	Weight (g)	Body (mm)	Tail[1] (mm)	Hindfoot (mm)	Ear from notch (mm)
Peromyscus maniculatus						
Islands	418	22.2 (21.9, 22.6)	84.7 (84.1, 85.3)	84.2 (83.0, 85.5)	21.5 (21.4, 21.6)	17.6 (17.5, 17.7)
Peninsula	9	19.2 (17.4, 20.9)	85.3 (79.5, 91.2)	83.4 (79.0, 87.8)	20.9 (20.4, 21.4)	18.1 (17.5, 18.7)
P. eremicus	14	16.7 (15.3, 18.0)	78.4 (75.3, 81.4)	108.8 (105.1, 112.5)	19.1 (18.7, 19.5)	18.1 (17.5, 18.6)
P. crinitus	4	15.0 (12.1, 17.9)	78.0 (72.0, 84.0)	106.5 (96.2, 116.8)	19.3 (18.5, 20.0)	17.5 (14.7, 20.3)
Chaetodipus baileyi						
Islands	155	20.3 (19.7, 20.9)	82.6 (81.6, 83.6)	96.2 (90.5, 101.9)	23.3 (23.1, 23.5)	8.9 (8.8, 9.0)
Peninsula	28	20.1 (18.9, 21.3)	80.9 (78.8, 82.9)	104.5 (92.7, 116.2)	23.8 (23.4, 24.1)	9.0 (8.8, 9.1)
C. spinatus	36	14.5 (13.8, 15.2)	71.8 (70.4, 73.2)	86.1 (71.3, 100.8)	21.3 (20.9, 21.6)	8.2 (7.9, 8.4)
C. arenarius	19	11.4 (10.7, 12.2)	69.4 (58.9, 79.8)	70.7 (53.0, 88.5)	21.3 (20.7, 21.9)	7.3 (6.8, 7.8)

[1] Sample size for tail lengths were slightly lower than N because some individuals had missing or damaged tails.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maniculatus, P. eremicus, P. crinitus, Ammospermophilus leucurus) were captured in a total of >6000 trap-nights (TN), but only two species were recorded on islands. These were identified as *P. maniculatus* and *C. baileyi* based on pelage characteristics and comparisons of morphological measurements (taken from live individuals) to those of individuals captured on the adjacent mainland (Table 1). Lawlor (1971) also reported *P. maniculatus* and *Perognathus* (= *Chaetodipus*) *baileyi* from Smith, the largest island (9.13 km^2) in Bahía de los Angeles. Both species are relatively uncommon on islands in the Gulf; the only other records of insular *C. baileyi* are from Tiburón and Monserrate, and of *P. maniculatus,* from Willard in Bahía de San Luis Gonzaga, some 120 km north (Lawlor 1983). In contrast, *C. spinatus* and *P. eremicus* and their islands derivatives inhabit nearby Angel de la Guarda and its satellite islands, as well as several islands in the San Lorenzo chain farther south (Gill 1981; Lawlor 1983), but were not found on any of the islands I surveyed. Because our Mexican research permits only permitted live-trapping, I did not collect voucher specimens or attempt to determine the subspecies status of insular populations.

P. maniculatus was more widespread among islands than *C. baileyi,* inhabiting nine of the 14 islands in Bahía de los Angeles and one of the four islands in and near Bahía las Animas (Fig. 1). *C. baileyi* was captured on only three islands, all of which were also inhabited by *P. maniculatus.* No mice were caught on any of the other eight islands surveyed, all of which were very small (<0.05 km^2; Polis et al. 1997). Although trapping effort was relatively low on these islands (14-40 TN; Fig. 1) and they were only trapped on one occasion, a similar effort was sufficient to document the presence of rodents on other islands.

Many of the islands inhabited by *P. maniculatus* were small (<0.2 km^2 in area) and located relatively far (>2.5 km) from the peninsula (Fig. 1), although most of these were <1.5 km from larger islands (Smith, Ventana) that may act as source populations. Four of the islands lacking mice were larger than the smallest island where *P. maniculatus* was captured (Blanca; 0.03 km^2). These islands were not especially isolated, but their surfaces tended to be more solid and less friable, and with fewer talus piles, which may not provide enough cover to support rodent populations consistently. The presence of *C. baileyi* on Mitlán, which is <200 m from Smith, was not surprising, but Pata, the other small island inhabited by *C. baileyi,* is much more isolated from potential source populations (≥2.5 km from both Smith and the peninsula), and thus may have been occupied by *C. baileyi* since submergence in the late Pleistocene (Gastil et al. 1983). To my knowledge, this is the smallest island (0.18 km^2) known be inhabited by pocket mice (*Chae-*

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Fig. 1. Map of Bahía de los Angeles, Baja California, México, showing the location of Gulf of California islands surveyed for rodents. *Peromyscus maniculatus* was captured on ten islands (island number, total trapping effort during 1997-2000): Coronadito (**1**, 108 TN); Smith (**2**, 2070 TN); Mitlán (**3**, 220 TN); Piojo (**4**, 180 TN); Pata (**5**, 468 TN); Bota (**6**, 264 TN); Flecha (**8**, 304 TN); Ventana (**11**, 558 TN); Cabeza de Caballo (**12**, 270 TN); and Blanca (**16**, 108 TN). *Chaetodipus baileyi* was only captured on Smith (**2**), Mitlán (**3**), and Pata (**5**). Islands where no mice were captured: Jorobado (**7**, 36 TN); Llave (**9**, 40 TN); Cerraja (**10**, 36 TN); Gemelos West and East (**13–14**, 36 TN each); Pescador (**15**, 36 TN); and Las Animas Norte and Sur (**17–18**, 14 TN each). Locations of 12 of the 14 mainland trapping sites are denoted with an "X"; the other two sites were 20 km inland.

todipus, Perognathus), which are granivorous and tend to be restricted to larger islands with high plant diversity and, hence, consistent seed production (Lawlor 1983). Omnivores like *Peromyscus* are more common on Gulf islands and elsewhere, in part because they can monopolize a broader range of animal and plant resources, including marine-based foods (Stapp et al. 1999). *Peromyscus* may also be more likely than *Chaetodipus* to disperse over-water because it lives and regularly forages near shore and commonly invades human encampments (P. Stapp, pers. obs). Despite its abundance on islands, however, *P. maniculatus* was only captured at one of the mainland sites, an area of coastal marsh near Punta La Gringa. *C. baileyi* was captured at nine of the 14 locations on the peninsula, although it was less abundant than *C. spinatus* in most areas. The vegetation and substrate of most of the mainland sites were qualitatively similar to those of the islands, so factors other than habitat (e.g., competition, predation) may contribute to the local scarcity of *C. baileyi,* and especially *P. maniculatus,* on the peninsula. It is not yet known if the insular populations of these species are distinct genetically or taxonomically from those on the mainland, but they contribute to the biological diversity of islands in the central Gulf, which are protected internationally as a Biosphere Reserve, and may be important for the conservation of these species in Baja California.

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Interspecific Association Between Blackbrush and its Three Commonly Associated Woody Species in Southern Nevada

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Coleogyne ramosissima (Blackbrush) dominate relatively large areas of vegetation in southern Nevada and the Mojave Desert. *Coleogyne* shrublands are distributed at mid-elevations between *Larrea tridentata-Ambrosia dumosa* (creosote bush-white bursage) shrublands below and *Pinus monopohylla-Juniperus osteosperma* (pinyon pine-Utah juniper) woodlands above. Their current distributions were probably developed since the last pluvial period (20,000–10,000 B.P.; Bradley 1964).

Plant community can be defined as a complex assemblage of plant species which show a definite affinity or association with each other (Kent and Coker 1992). *Coleogyne* plants tend to grow together with certain woody species, but not others. These ideas can be initially represented by the concepts of positive and negative association. Positive association implies that two plant species appear together more often than would be expected by chance or random events. Conversely, negative association means that two species appear together less often than would be expected by chance (Kent and Coker 1992).

The degree of association between species in a set of samples can be quantified. Chi-square analysis is often used as a method of measuring association between plant species. The objective of this study is to quantify the degree of association between *Coleogyne ramosissima* (blackbrush) and three of its commonly associated woody species, *Yucca brevifolia* (Joshua tree), *Encelia virginensis* (brittlebush), and *Gutierrezia sarothrae* (snakeweed) in the Spring Mountains and Sheep Range of southern Nevada.

A total of 181, 100-m^2 circular plots were established among the 15 transects that spanned the elevational distribution of *Coleogyne* in the Spring Mountains (12 transects) and the Sheep Range (3 transects) in southern Nevada. Transects began in the upper portions of the *Larrea-Ambrosia* shrublands, through the entire *Coleogyne* belts, and terminated at the lower portions of the *Pinus-Juniperus* woodlands. Transects in the Spring Mountains were subdivided into three geographical areas based on aspect. Transects contained 9 to 16 plots depending on the range of upper and lower elevational boundaries of the *Coleogyne* vegetation zone. Habitats included in the transects were classified as slopes, flat surfaces (terraces), and dry washes. Cliffs and stream beds were excluded, but substitute plots were randomly established at the identical elevation. All 181 plots were placed at a fixed attitudinal interval of 65 m for each transect. All plots were located near major access roads, but were at least 50 m away from roadways to eliminate road effects.

Within each plot, the presence/absence (frequency) of *Coleogyne, Yucca, Encelia,* and *Gutierrezia* plants was recorded. Three pairs of species association were

Table 1. Summary from Chi-square (χ^2) analysis of the interspecific association between *Coleogyne* and three of its commonly associated woody species in the Spring Mountains and Sheep Range of southern Nevada.

Association	χ^2	P-value	r
Coleogyne-Yucca	18.71	0.0000	0.23
Coleogyne-Gutierrezia	11.35	0.0008	0.29
Coleogyne-Encelia	5.36	0.0206	0.10

considered: *Coleogyne-Yucca, Coleogyne-Gutierrezia,* and *Coleogyne-Encelia.* Interspecific association between these three pairs of plant species was tested with Chi-square analysis, and statistical significance was determined at $P \leq 0.05$ (Analytical Software 1994).

Coleogyne vegetation zones range from approximately 1,350 m in elevation on north-facing slopes to over 2,000 m on south-facing slopes in the Spring Mountains and Sheep Range of southern Nevada. The mean elevational range of 15 transects is 1120 to 1835 m (Lei 1995a, b).

Coleogyne was significantly positively associated with *Yucca* (Table 1). A value of $r = 0.0$ indicates that the two species occurred together as frequently as expected by chance; $r = 1.0$ implies that two species always appeared together; $r = -1.0$ implies that they never appeared together (Mueller-Dombois and Ellenberg 1974). The tabular arrangement of the 2 * 2 contingency table permits a comparison between the number of quadrats actually occupied by the species with those expected under the hypothesis of a random dispersion of the plants on the ground (Mueller-Dombois and Ellenberg 1974). This hypothesis postulates that the number of occurrences of all combinations follows a predictable pattern as mathematically calculated by the X^2 distribution. Chi-square tests are used to determine if the proportion of samples containing one species is significantly correlated with the occurrence of a second species (Mueller-Dombois and Ellenberg 1974).

There are reasons why positive *Coleogyne-Yucca* association exists at mid-elevations in southern Nevada. *Yucca* plants were found in an elevational range of 700 to 1775 m on dry slopes and terraces in this study. *Yucca* may be in codominance with *Larrea, Coleogyne,* or *Juniperus* (Turner 1982). Of the three codominant species, *Yucca* are most frequently associated with *Coleogyne,* yet *Yucca* contribute relatively little to the total vegetation cover and stand composition. *Yucca*'s dominance is more visual because of their tall stature rather than their high density or canopy area. *Yucca* usually grow on sandy, loamy, or fine gravelly soils with minimum surface-water runoff (Turner 1982).

Although not quantitatively examined in this study, recruitment of *Yucca* is largely dependent upon the existence of microclimates that occur under the canopies of perennial shrubs, most importantly *Coleogyne.* Advantages of seed germination within the canopy of a (nurse) plant may include higher soil moisture and nutrients, along with reduced insolation, soil surface temperatures, evapotranspiration demand, herbivory, and reduced wind desiccation (Brittingham and Walker 2000). Disadvantages of seed germination under a nurse plant may include competition for resources if the adult plant has a near-surface root system, reduced net carbon gain, and allelopathy (Franco and Nobel 1989; Brittingham and Walker 2000).

Maximum seedling growth occurs with a soil temperature of 21°C (Wallace 1970); moderate air temperatures produce the highest net photosynthesis rate in *Yucca* (Smith et al. 1983). Moderate plant tissue temperature appears to be the most critical parameter favoring the survival of *Yucca* seedlings (Brittingham and Walker 2000). *Coleogyne* plants are correlated with *Yucca* seedlings in greater numbers than expected based on their density or canopy area (Brittingham and Walker 2000). Recruitment of *Yucca* is based upon microhabitat alterations by specific nurse plants, and upon subtle variations in light and shade that have important implications on physiological/ecological requirements for germination and survival of *Yucca.*

Moreover, both *Coleogyne-Gutierrezia* and *Coleogyne-Encelia* associations were positively correlated in occurrence (Table 1), but were negatively correlated in abundance (Data not shown). Of these two pairs of species associations, *Coleogyne* and *Gutierrezia* revealed a more positive correlation (Table 1). In this study, *Gutierrezia* and *Encelia* plants were found below 2200 and 1525 m in elevation, respectively. *Gutierrezia* occupied a fairly wide elevational range, from the upper portions of *Larrea-Ambrosia* through the lower portions of *Pinyon-Juniperus* vegetation zones. However, *Encelia* could not become established in relatively high elevations above the *Coleogyne* zones. *Gutierrezia* and *Encelia* were frequently established in disturbed habitats. Mature *Coleogyne* shrubs were completely replaced by open stands of *Gutierrezia* and *Encelia* in fire disturbed habitats in southern Nevada (Lei 2000). *Gutierrezia* made its first appearance over other woody shrub species in areas that experienced moderate burns, suggesting that regeneration of *Gutierrezia* is possible within five years after a major fire disturbance (Lei 2000). *Gutierrezia* plants appear to be opportunistic and rapidly colonize disturbed sites, presumably due to rapid reproductive potential, high seed production, high germination rate, and early seedling establishment (Osman and Pieper 1988; Lei 2000).

Encelia also resprouted or produced seedlings fairly rapidly after fire damage in southern Nevada (Lei 2000). From casual observations, both *Encelia* and *Gutierrezia* plants rapidly invaded open areas created by fire. Soil seed densities of these two woody pioneer species were significantly higher in burned areas compared adjacent unburned areas in southern Nevada (Lei 2001). The significantly fewer number of seeds in burned areas suggest that *Coleogyne* shrubland will require a long period of time to return to pre-burn conditions following fire disturbance (Lei 2001).

Furthermore, *Encelia* and *Gutierrezia* also occurred in wash habitats within the mature, edaphically stable *Coleogyne* shrublands. Although intermittent washes are dry throughout much of the year, these washes can rapidly fill with running surface water during and shortly after major storm events. *Coleogyne* plants were nearly absent in active washes. Long-term soil stability is important for *Coleogyne* plants since they typically occur on old, stable geomorphic surfaces with minimal disturbances in southern California (Webb et al. 1987).

The Chi-square test simply relies on frequency values, based on the presence and absence of species, to determine the degree of association between species. Yet, this test does not incorporate other values, such as density and canopy area.

Plant species association derived from the Chi-Square analysis are strictly correlative. Exactly why two species show a positive or a negative association will require additional investigations, including various experiments under laboratory and natural field conditions. The most common reason why two species regularly occur together is because they share a similar set of environmental conditions. However, further ecological investigations often reveal such an explanation to be over-simplistic, and factors such as plant species strategies, interspecific competition, and biotic interactions also need to be taken into account (Kent and Coker 1992). In this study, the *Coleogyne-Yucca* association involves in both biotic and abiotic factors. Seed germination and seedling establishment under a mature nurse plant may alleviate some of the environmental extremes and adverse biological interactions during the most fragile stages of the *Yucca* life cycle. Both *Coleogyne-Gutierrezia* and *Coleogyne-Encelia* associations were positively correlated in occurrence, but were negatively correlated in abundance. Such an inverse quantitative relationship is intriguing, and may indicate differing degrees of competitive relations along an environmental gradient in the Spring Mountains and Sheep Range of southern Nevada.

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Gastrointestinal Nematodes of the Isla Cerralvo Spiny Lizard, *Sceloporus grandaevus* (Phrynosomatidae) from Baja California Sur, Mexico

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The Isla Cerralvo Spiny Lizard, *Sceloporus grandaevus* is endemic to Isla Cerralvo (24°30′N, 109°40′W), Baja California Sur, Mexico. It commonly occurs in rocky arroyos, avoiding areas devoid of vegetation (Grismer 2002). To our knowledge, helminths have not been reported from *S. grandaevus*. We herein report two nematode species from *S. grandaevus*.

Twenty *Sceloporus grandaevus* (mean snout-vent length, 61.1 mm ± 8.9 SD, range = 50–78 mm) collected July 1960 on the southwest portion of Isla Cerralvo were examined (Appendix). Lizards were fixed originally in 10% formalin and preserved in 70% ethanol. The body cavity had been opened by previous investigators; however, the internal organs were intact. The digestive tract was removed, opened longitudinally and the esophagus, stomach, small and large intestines were searched for helminths using a dissecting microscope. Only nematodes were found. These were placed on microscope slides and allowed to clear in a drop of undiluted glycerol. A coverslip was added and the nematodes were identified with a compound microscope.

Two species of Nematoda, *Atractis penneri* (Gambino, 1957) and *Thubunaea iguanae* Telford, 1965 were found. Selected specimens were placed in vials of 70% ethanol and deposited in the United States National Parasite Collection, (USNPC), Beltsville, Maryland: *Atractis penneri* USNPC 92115; *Thubunaea iguanae* USNPC 92116. Number of individuals, prevalence (percentage of infected lizards), mean intensity ± 1 SD (mean number of helminths per infected host) range and infection site, respectively, for each neamtode species are: *Atractis penneri,* 1,216, 20%, 304 ± 239 SD, 35–525, large intestine; *Thubunaea iguanae,* 6, 25%, 1 ± 0.4 SD, 1–2, stomach, small intestine.

Atractis penneri is widespread and has been reported in lizards of the genera *Callisaurus*, *Crotaphytus*, *Gambelia*, *Holbrookia*, *Phrynosoma*, *Sceloporus*, *Uma* and *Uta* occurring from the western United States, northern Mexico and Baja California (Baker 1987).

Thubunaea iguanae was described by Telford (1965) from the stomachs of lizards collected in California and Mexico. He reported its occurrence from Isla San Esteban in the Gulf of California but the lizard host was not given. *Thubunaea*

Table 1. Reports of *Atractis penneri* and *Thubunaea iguanae* in lizards from Baja California, Mexico.

Nematode Lizard host	Locality	Prevalence	Reference
Atractis penneri			
Callisaurus draconoides	Isla Angel de la Guarda	5/12, 42%	Gambino and Heynemann 1960
	Bahía San Francisquito	2/2, 100%	Gambino and Heynemann 1960
	not given	13/34, 38%	Gambino and Heynemann 1960
Gambelia wislizenii	not given	1/1, 100%	Gambino and Heynemann 1960
Petrosaurus sp.	not given	1/1, 100%	Gambino and Heynemann 1960
Sceloporus grandaevus	Isla Cerralvo	4/20, 20%	this study
Sceloporus magister	not given	1/1, 100%	Gambino and Heynemann 1960
Thubunaea iguanae			
Sceloporus grandaevus	Isla Cerralvo	5/20, 25%	this study
Unidentified lizard(s)	not given	not stated	Telford 1965

iguanae is primarily known from California wehre it has been reported from *Callisaurus*, Cnemidophorus, *Crotaphytus*, *Sceloporus*, *Uma*, *Uta* and *Xantusia* (Baker 1987).

Sceloporus grandaevus is a new host record for *Atractis penneri* and *Thubunaea iguanae* and Isla Cerralvo is a new locality for both nematode species. A list of lizards from Baja California found to harbor *A. penneri* and *T. iguanae* is presented in Table 1.

Acknowledgments

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Appendix

Specimens of *Sceloporus grandaevus* examined from the herpetology collection of the Natural History Museum of Los Angeles County (LACM): 9935, 9940, 9942, 9948, 9956, 9963-9966, 9970, 9972, 9977, 9979, 36481-36483, 36486, 36487, 36496, 36500.

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